000608_KJ06_04_DT1221

Site Assessment Report for Wilcox Refinery Bristow, Creek County, Oklahoma

Contract No. 68-W6-0013

March 1999

Prepared for:

U.S. ENVIRONMENTAL PROTECTION AGENCY
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MEMORANDUM

Date: March 30, 1999

To: Don Smith, Task Manager
EPA Region 6 Response and Prevention Branch

Thru: Henry Thompson, Jr., Project Officer
EPA Region 6 Program Management Branch

Thru: Chris Quina, STL
EPA Region 6 Superfund Technical Assessment and Response Team

From: Thomas Beer, Project Manager
EPA Region 6 Superfund Technical Assessment and Response Team

Subj: Site Assessment Report: Wilcox Refinery
Bristow, Creek County, Oklahoma
CERCLIS No. OKD001010917
TDD#: S06-98-03-0009
PAN: 052601SFXX
Lat: 35°50'30"N Long: 96°23'00"W

Enclosed is the site assessment report for the Wilcox Refinery site in Bristow, Creek County, Oklahoma. The report provides background information, and a detailed discussion of the sampling history and results for this site. The most significant findings are summarized in Section 6.

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1 Introduction

Pursuant to Contract No. 68-W6-0013, the U.S. Environmental Protection Agency (EPA) tasked Ecology and Environment, Inc., (E & E), the Region 6 Superfund Technical Assistance and Response Team (START) contractor, to perform a Site Assessment (SA) at the Wilcox Oil Company (Wilcox) refinery site (EPA Identification No. OKD0010917) located in Bristow, Creek County, Oklahoma. The site assessment follows a Preliminary Assessment (PA) conducted by the Oklahoma Department of Environmental Quality (ODEQ) in December 1994 (ODEQ 1994a), and an Expanded Site Inspection (ESI) performed by Roy F. Weston, Inc., for ODEQ in March 1997 (Weston 1997).

The Wilcox refinery site includes approximately 98 acres of an abandoned and demolished oil refinery and an associated tank farm area. The site is located on the northeastern outskirts of Bristow, near Interstate Highway 44 and approximately 35 miles southwest of Tulsa, Oklahoma. A site location map derived from the U.S. Geological Survey (USGS) Bristow and Slick quadrangles of the 7.5-minute topographic map series is presented in Figure 1-1. The Wilcox site is located approximately 0.2 mile east of State Highway 66, to the east of the Saint Louis and San Francisco (SL&SF) railroad tracks, and south of an unnamed section line road, variously referred to as Refinery Road or Wilcox Road. The geographic coordinates at the northwest corner of the site are approximately 35°50'30" north latitude and 96°23'00" west longitude.

START was tasked to identify the area and extent of contamination by performing a site investigation. START was specifically charged to:

- Conduct an oil spill response;
- Coordinate with federal, state, and local officials;
- Document the area and extent of spill impact;

- Identify and document cause/probable cause;
- Provide maps, sketches, and photographic documentation;
- Prepare a waste assessment (HAZCAT);
- Conduct a SA for potential removal action under the National Contingency Plan (NCP) and Oil Pollution Act (OPA) of 1990; and
- Determine threat to navigable waters of the United States.

To meet the objectives of this program, E & E performed two phases of field work: April 27, April 28, and June 1 to June 4, 1998; and from August 3 to August 6, 1998. The first phase of field work was postponed from April to June after the collection of two soil and two sediment samples, due to saturated ground conditions at the site after heavy overnight rains. Field activities included the collection of subsurface soil, ground water, surface water, and sediment samples. The samples were submitted for laboratory analysis to determine the presence of benzene, toluene, ethylbenzene, and xylene (BTEX) compounds, polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPH), metals, and hydrogen ion concentration (pH). Analytical results were used to determine the presence of, and assess the threat to navigable waters from, potential site related contaminants.

OK2601a.CDR 06

N

SCALE 1:24,000

1 1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET

QUADRANGLE LOCATION

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& Response Team - Region 6

CERCLIS/CASE#: OKD001010917 TDD#: S06-9803-0009

SOURCE: U.S.G.S. 7.5 MIN. TOPOGRAPHIC QUADRANGLES
BRISTOW AND SLICK, OKLAHOMA

FIGURE 1-1 SITE LOCATION MAP
WILCOX REFINERY
BRISTOW, OKLAHOMA

2 Background Information

2.1 Site Location and Setting

This section summarizes existing information for the project site. The Wilcox refinery site is located northeast of the City of Bristow, Creek County, Oklahoma (Figure 1-1). The site covers approximately 98 acres and is the location of a former oil refinery and tank farm. Refining began at the site during the 1920s and ended in the 1960s, when the site was abandoned and most steel structures were salvaged and removed. The site is also bordered to the northwest and west by former refinery sites. The Wilcox site includes remnants of the refinery buildings, backfilled pits and ponds, and a number of circular berms that surrounded former large aboveground storage tanks. A site plan showing the layout of the site is presented as Figure 2-1.

2.2 Regional Geology and Hydrogeology

2.2.1 Geology

Based on the soil survey for Creek County, the site contains several soil series: the Stephensville and Darnell fine sandy loams, sloping and gently sloping; the Verdigris silt loam; and Oil-waste land (USDA 1959). The Stephensville and Darnell fine sandy loams cover the majority of the site. These soils consist of shallow to moderately deep upland soils developed over reddish-yellow to red sandstone or interbedded sandstone and sandy shale. Runoff is slow to moderate, but internal drainage is moderate to rapid. The site-specific soils characterized in this investigation are presented in the soil boring logs (Appendix A).

The Verdigris silt loam is located in the southwestern portion of the site, along Sand Creek. These soils occupy the flood plains of streams and are moderately well drained; however, they are flooded occasionally to frequently. Parent material consists of slightly acid to weakly alkaline alluvial sediments washed from soils of the prairies.

The Oil-waste land was mapped in discrete areas throughout the site in 1959. These soils are in the tank farm and former refinery equipment areas. The areas mapped in this miscellaneous land type have been practically ruined for agricultural use by oil and salt-water waste from oil wells and production facilities. They are generally gullied and eroded and were barren of vegetation. They ranged in size from 1 acre to several acres (USDA 1959).

2.2.2 Hydrogeology

The Barnsdall Formation is approximately 200 feet thick at the Wilcox site and consists of massive to thin beds of coarse to fine grain sandstone, irregularly interbedded with sandy to silty shale (USGS 1977). Sandstone outcrops of the Barnsdall Formation are common throughout the site, and potentially receive groundwater recharge from downward infiltration of direct precipitation at the surface, as well as infiltration from shallow, perched ground water zones. The Barnsdall Formation is a bedrock aquifer but is not considered to be a Principal Ground Water Resource by the Oklahoma State Department of Health (OSDH) (ODEQ 1994a). However, the site is in close proximity to the Vamoosa-Ada aquifer, an important central Oklahoma regional drinking water aquifer, located west of the site. The site is within the potential recharge area for the Vamoosa-Ada aquifer, as shown in Figure 2-2 (OSDH 1983).

The upper part of the Barnsdall Formation and the Sand Creek alluvial aquifer are unconfined, with a shallow water table. The site is in a potential recharge area and thus is susceptible to ground water contamination from petroleum waste or contaminated soils. Depths to seasonal perched water zones are less than 10 feet and the shallowest regional water bearing formation is reportedly less than 25 feet below ground surface (bgs) (ODEQ 1994a). However, a depth of 45 to 60 feet was reported for the first water saturated sandstone in a nearby former domestic water well ((b) (6) 1998). In summary, the possible ground water contamination mechanisms occurring at the site are 1) recharge to the shallow part of the Barnsdall Formation on site, 2) low potential recharge to the Vamoosa-Ada aquifer west of the site, and 3) discharge of perched ground water to the alluvial aquifer along Sand Creek to the south.

2.3 Site Description and History

2.3.1 Site Description

The Wilcox site includes remnants of an inactive oil refinery and associated tank farm. According to ODEQ personnel, the site boundaries have been revised from those defined in the 1994 PA to include only those areas in which Wilcox Oil Company conducted operations. Although Wilcox Oil Company owned property west of the railroad tracks (currently occupied

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by the First Assembly of God Church and pastor's residence), the facility only operated on the lands east of the SL&SF tracks. Other refineries operated on the west side of the railroad tracks (Lorraine Refinery) and north of Refinery Road (Ohio Oil). The current project site covers approximately 98 acres and includes the northern portion of Section 29, Township 16 North, Range 9 East (Indian Meridian) (ODEQ 1994b). The site can be divided into two former operational areas, the refinery area, and the tank farm, with four current property owners, as described below.

The former refinery area, currently owned by (b) (6) and his son (b) (6), is fenced and covers approximately 18 acres at the west end of the project site (ODEQ 1994b). This area is bounded to the south by Sand Creek, to the east by an intermittent tributary to Sand Creek (Tributary 1), by the SL&SF railroad tracks to the west, and by Refinery Road to the north (Figure 2-1). Most of the refinery structures and tanks have been salvaged and removed or are in ruins. Four empty aboveground storage tanks (less than 150,000 gallons capacity each) remain standing on the refinery portion of the property, in addition to a substantial number of abandoned structures, rusted equipment, and partially buried pipelines. The ESI identified a number of potential waste source areas, and provided a basis for further subsurface investigation. These potential waste source areas are depicted in Figure 2-3, along with observed surface drainage pathways from sources toward stream channels. The bare, unvegetated area located in the south-central portion of the refinery area is a former pond, apparently backfilled with solid refinery process waste. This material was subject to HAZCAT testing, as described in Section 3.6. A former refinery office building in the northern part of the refinery has been converted to a residence. An intermittent creek (Tributary 1) flows southward along the eastern edge of the refinery area through a small dam in the southeast corner of the refinery area ((b) (6) Pond) and into Sand Creek.

The former tank farm, currently mostly owned by (b) (6), covers approximately 80 acres and contains waste pits, ponds, and a number of circular berm areas that surrounded former large ASTs (Figure 2-3). All of the tanks have been cut down and removed for salvage; however, visible remnants of the metal tank bottoms and tank bottom sludge (TBS) remain. Many of the berms surrounding the pits, ponds, and former tanks have recently been cut or leveled to prevent ponding and, in some cases, to release liquid tarry waste from the impoundments. An intermittent creek (Tributary 2) is located in the eastern portion of the tank farm and flows south to Sand Creek (Figure 2-3).

(b) (6) owns 3.6 acres of land in the west central portion of the site, including a stock watering pond on Tributary 1 (b) (6) Pond). Three people, (b) (6) and their daughter, live at the (b) (6) residence. The (b) (6) raise chickens, rabbits, and cattle on their property. Based on aerial photographs, the (b) (6) residence appears to be on top of a former refinery surface impoundment. Aerial photos also indicate that their property includes portions of a former large aboveground storage tank berm area to the north of their house, in addition to a second surface impoundment to the south of the house (Figure 2-3).

A 1.15-acre, fenced, former pipeline pumping station that is currently owned by Sun Oil Company exists in the north-central portion of the site (Figure 2-3). An active Williams Company petroleum pipeline extends from southeast to northwest across the middle of the site and through the Sun Oil property, on a leased right-of-way (ROW). The pipeline ROW apparently dates from the time of purchase by Wilcox Oil Company in 1929 (Table 1; Figure 2-3).

2.3.2 Site History

Wilcox Oil Company operated as a crude oil refinery from the 1920s until the property was sold in November 1963 (ODEQ 1994b). According to a 1930 article published in *The Refiner and Natural Gasoline Manufacturer*, the Wilcox Oil Company refinery was operated as a pilot project from about 1920 to 1928, with a capacity of 1,000 barrels of oil per day, by Riley Petroleum Company (Reid 1930, cited by ODEQ 1994b). Wilcox Oil Company acquired the original 10-acre refinery property (NE¼, NW¼, NW¼ of Section 29) in 1928 from A.A. Rollestone (ODEQ 1994b). A modernized skimming and cracking plant was constructed in 1929. The upgraded facility had an operating capacity of 4,000 barrels of crude oil per day. The main components of the system consisted of a skimming plant, cracking unit, and redistillation battery with a vapor recovery system and continuous treating equipment. The crude oil was brought directly from the nearby oil fields, eliminating some storage and handling facilities, but resulting in crude with high bottom sediment and water content (ODEQ 1994a).

At some unknown later date, the Wilcox Oil Company expanded operations by acquiring the former Lorraine refinery facility located west of the SL&SF railroad, and the tank farm area to the east of the refinery. The company sold the original site plus the expanded areas, totaling approximately 110 acres, to Wendel Sandlin on November 1, 1963. Most of the equipment and storage tanks that remained on site in 1963 were auctioned and have since been salvaged for scrap iron by private landowners and opportunistic salvagers. The Wilcox Oil Company no longer operates in Oklahoma, and, based on information acquired from the Oklahoma Secretary

of State's Office, the company merged with Tenneco Oil Company in 1967. According to file information, (b) (6) acquired the original refinery property from (b) (6) on March 27, 1973 (ODEQ 1994b). (b) (6) acquired the bulk of the current Wilcox site from (b) (6) (b) (6) in 1993 (Appendix B). A summary of current site owners and historical property transfers is presented in Table 2-1.

2.4 Previous Investigations

The EPA completed a Potential Hazardous Waste Site Identification form on June 7, 1994. In response, the ODEQ completed a PA for the Wilcox site and adjacent refinery and tank farm sites, on December 15, 1994. The PA indicated that contamination of soil and ground water at the site had been observed and that potential receptors exist for these pathways (ODEQ 1994a). The PA then recommended a site inspection be conducted in order to better characterize the site and to determine whether threats to human health and the environment exist. The ESI was conducted by Roy F. Weston (Weston) for ODEQ in November 1996, and their results were presented in the ESI report dated March 1997.

The ESI revealed the presence of numerous backfilled ponds and oily waste pits, 11 large tank bottom areas, assorted waste disposal areas, and other potential contaminant sources (Figure 2-3). Many of the tank bottom areas contained a thin layer of oily, tarry, black asphalt-like material generally referred to as tank bottom sludge (TBS). Former containment features of the impoundments and tank bottom areas were cut or leveled after site closure, thus facilitating surface migration of source contaminants. Based on surface soil, stream sediment, and oily waste sampling results from the ESI, the contaminants of concern at the site are total petroleum hydrocarbons (TPH), benzene, selected polycyclic aromatic hydrocarbons (PAHs), and selected metals. A summary of the ESI analytical results is presented in Table 2-2.

E & E conducted a site discovery survey under OPA in June 1997, and two site reconnaissance visits were performed by START in March and April 1998. During its site visits, START observed that the site owners had filled in Pond 1 and the 'oily waste' pit with site soil. The berm surrounding Pond 2 was breached and the pond drained toward Sand Creek. Four ASTs still remain on the (b) (6) property at the west end of the site. Of these ASTs, two are empty, and two contain thin layers of watery, oily sludge.

2.5 Hazards/Incidents of Concern

The presence of hazardous substances at the site is a concern. There are possible concerns associated with the sources at the site and the migration of, or exposure to, site-

attributable hazardous substances through the ground water, surface water, soil exposure, and air pathways. The site overlies a shallow unconfined aquifer that private residents north of the site use as a water source. In addition, the site overlies a potential recharge zone to the Vamoosa-Ada aquifer, a public water supply source. A release to surface water is of concern because of the proximity to surface water bodies and the lack of containment structures around potential waste sources. Wetland frontages occur in the downstream segments of Sand Creek, and further downstream in the Little Deep Fork Creek (Weston 1997). Areas of known surface soil and suspected subsurface soil contamination are located near and beneath on-site residences. However, on-site sources occur within fenced sections of private properties and the nearby population is relatively small. A release to the air to the nearby population is of some concern because of the known surface soil contamination at the site.

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Table 2-1

LAND OWNERSHIP HISTORY
WILCOX REFINERY, BRISTOW, OKLAHOMA

Address	Acreage (Parcel Location On Site)	Property Owners	Date of Transfer
(b) (6)	18 (Western 1/5th)	(b) (6)	1/22/79[1]
			3/27/73[1]
			4/21/67[1]
			3/6/67[1]
			7/15/66[1]
			11/1/63[1]
		Wilcox Oil Company	1/4/29[1]
	78.85 (Eastern 4/5th)	(b) (6)	Unknown
			1993[2]
			1992[3]
	3.6 (West Central)		1/95[3]
			Unknown
907 South Detroit Street Tulsa, OK 74102	1.15 (North West Central)	Sun Pipeline Co.[4]	Unknown

Key:

1 = Potentially Responsible Party (PRP) Search, Oklahoma Department of Environmental Quality (ODEQ), 12/12/94
2 = (b) (6) Personal Communication, 7/17/98
3 = Personal Communication, 7/28/98
4 = [redacted] Personal Communication, 7/21/98

Table 2-2

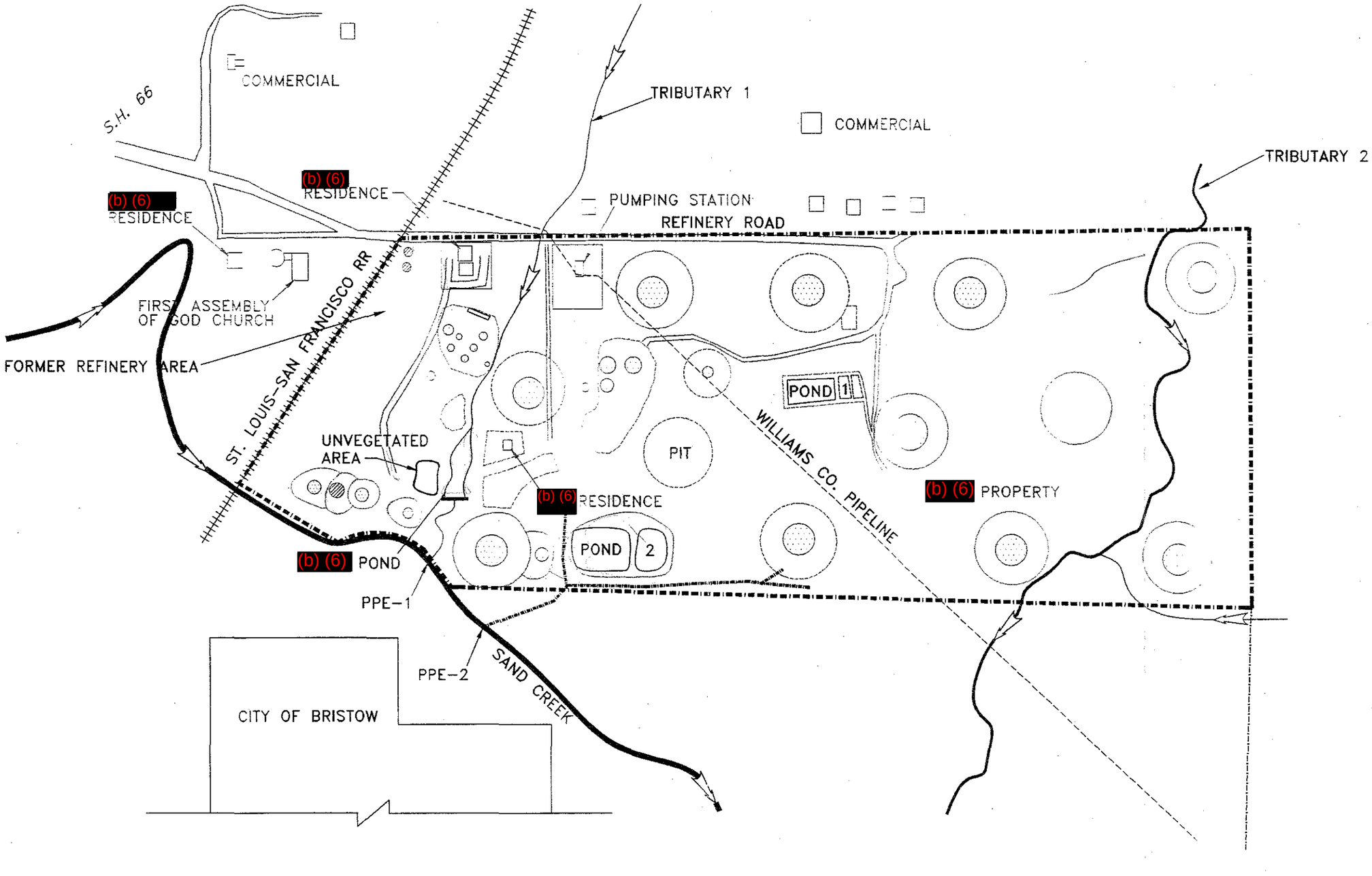
SUMMARY OF EXPANDED SITE INSPECTION
ANALYTICAL RESULTS
WILCOX REFINERY, BRISTOW, OKLAHOMA

Analyte	Maximum Concentration (mg/kg)			
	Oily Waste	Surface Soil	Stream Sediment	Background Soil
Acetone	2.2	48J		ND
Benzene	0.27			ND
Toluene				ND
Ethylbenzene				ND
Xylenes				ND
Benzo(ghi)perylene		0.44		ND
Chrysene		0.69		0.05
2-Methylnaphthalene	1,400			ND
Phenanthrene	520	0.79		0.034
Pyrene	260J	0.56		0.062
Pesticides/PCBs				ND
Total Petroleum Hydrocarbons	875,000	NA	NA	NA
Aluminum	22,100			5,580
Antimony	7.7			ND (4)
Arsenic	8.7			1.5
Barium	191			58.2
Beryllium	1.2			0.28
Copper	100	127	5.5 (upstream)	5.3
Cyanide	2			ND (0.7)
Lead	47,000	55,049J	117J (upstream)	26.3
Magnesium	5,080		6,260 (upstream)	744
Manganese	938			233
Mercury	0.11	0.18		ND (0.07)
Potassium	3,300			961
Selenium	0.84			ND (1)
Silver	2			ND (1)
Vanadium	38.1			11.2
Zinc	160	132	31.7 (upstream)	34.8

Note: Blank spaces indicate analyte was not detected at concentrations greater than three times background soil concentrations.
Shaded results exceed one or more To Be Considered materials in Section 5.1.1.

Key:

ESI - Expanded Site Inspection, Roy F. Weston, Inc., March 1997
J - Estimated value
L - Reported concentration is between the instrument detection limit and the CRDL
NA - Not analyzed
ND - Not detected
mg/kg - Milligrams per kilogram



LEGEND

- FORMER TANK LOCATION
- CUT/LEVELED BERM
- BERM
- BUILDING
- SITE BOUNDARY
- POND
- DRAINAGE DITCH
- EXISTING TANKS
- STREAM DIRECTION OF FLOW

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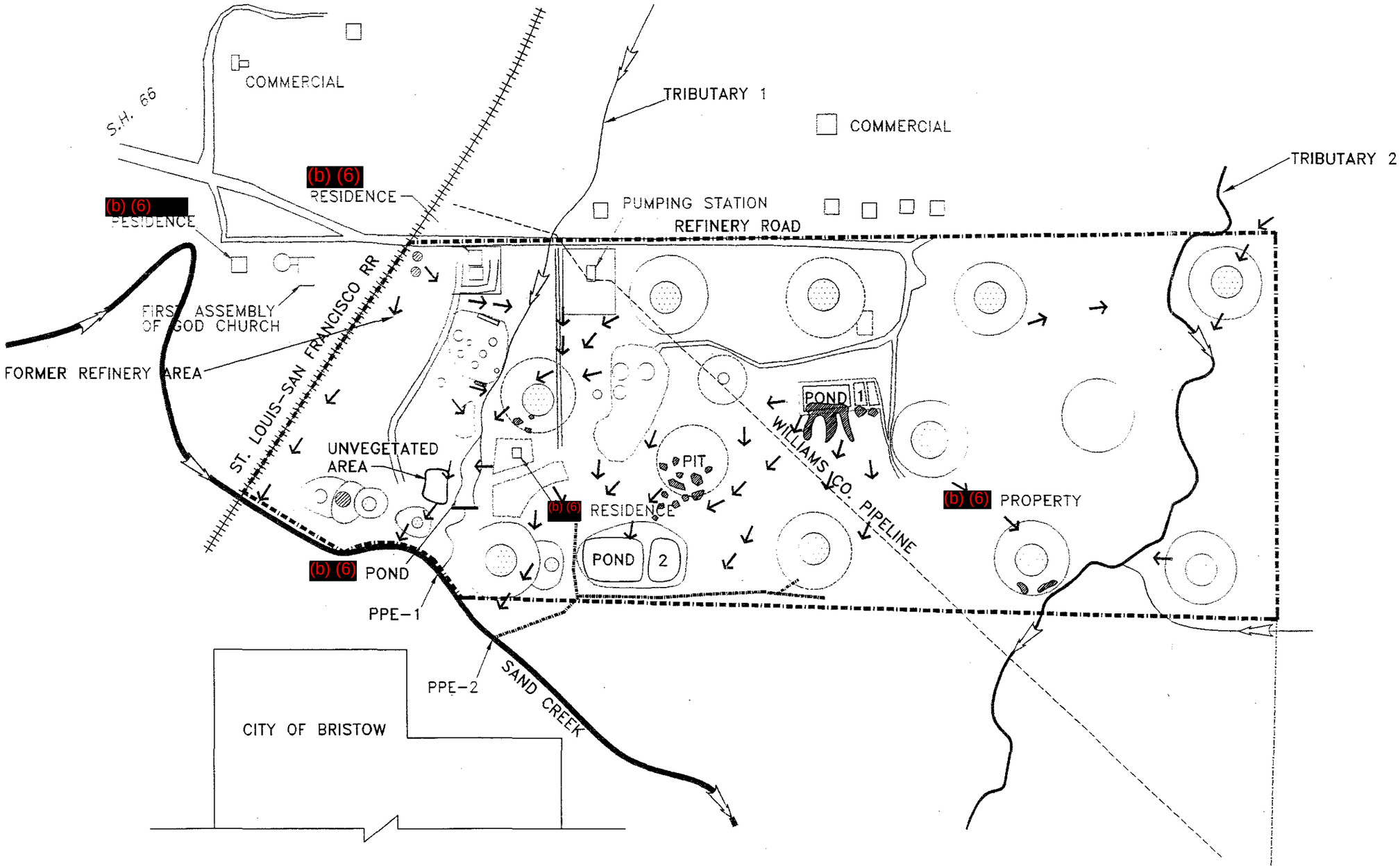
FIGURE 2-1 SITE PLAN
WILCOX REFINERY
BRISTOW, OKLAHOMA

TDD# S06-98-03-0009	Date: MARCH 31, 1999
PAN# 052601SFXX	P.M.: T. BEER

BASE MAP SOURCE: ROY F. WESTON INC., ESI REPORT, MARCH, 1997, FROM ACE AERIAL PHOTO, 1966.

OK2601c.DWG 06 WH



LEGEND

- POWER TANK LOCATION
- SITE BOUNDARY
- POND
- OILY SURFACE WASTE
- BERM
- DRAINAGE DITCH
- OVERLAND FLOW
- DIRECTION OF FLOW

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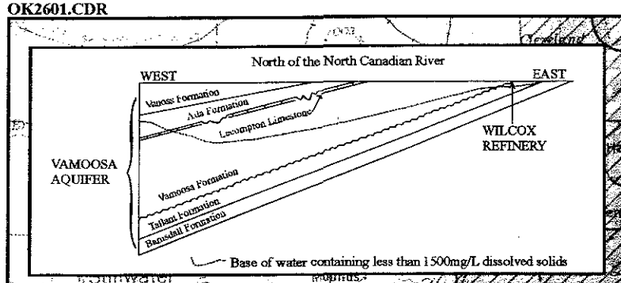
FIGURE 2-3 POTENTIAL WASTE SOURCES AND SURFACE DRAINAGE FEATURES
WILCOX REFINERY, BRISTOW, OKLAHOMA

TDD# S06-98-03-0009 Date: MARCH 31, 1999

PAN# 052601SFXX P.M.: T. BEER

BASE MAP SOURCE: ROY F. WESTON INC., ESI REPORT, MARCH, 1997, FROM ACE AERIAL PHOTO, 1966.

OK2601.CDR



VAMOOSA FORMATION

WILCOX REFINERY

OSCAR GROUP

LEGEND

POTENTIAL RECHARGE AREAS

RECHARGE AREAS

N

Scale: 1:500,000

1 inch equals approximately 8 miles

10 0 10 20 30 MILES 40

10 0 10 20 30 40 50 KILOMETERS

Base map modified from U.S. Geological Survey, 1:500,000 series, dated 1972

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PAN: 052601SFXX TDD# S06-98-03-0009 CERCLIS/CASE#: OKD001010917

SOURCE: U.S.G.S. Compiled by Kenneth Johnson
Oklahoma Geological Survey 1983

FIGURE 2-2 REGIONAL HYDROGEOLOGY
WILCOX REFINERY
BRISTOW, OKLAHOMA

QUADRANGLE LOCATION

3 Actions Taken

This section describes the field activities performed during the SA at Wilcox refinery. Field activities were performed in accordance with the *Sampling QA/QC Work Plans* and *Health and Safety Plan* developed for the site (E & E 1998a, b, c). Copies of the Phase 1 and 2 Work Plans, and the Health and Safety Plan are presented in Appendices C and D, respectively. Field activities were documented in the field logbook (Appendix E) and with photographs (Appendix F).

3.1 Source Evaluation and Sample Locations

Subsurface soil and ground water samples were taken in order to assess contaminant migration (vertical and horizontal), investigate geologic conditions, and determine the potential threat to navigable waters. Site access was obtained from each landowner prior to field mobilization (Appendix G). Samples collected during the first phase of work were generally collected at downgradient locations in relation to potential source areas identified from the ESI. The second phase of sampling concentrated on assessing the potential impacts to surface waters in Tributaries 1 and 2, from known source areas identified from the ESI and from the first phase sampling results. A summary of the rationale for each sample location is presented in Appendix H.

Soil, ground water, surface water, and sediment samples were collected at the site in order to identify site-related contaminants in environmental media. A total of 55 subsurface soil samples, eight groundwater samples, four surface water samples, two sediment samples, and 12 field quality control (QC) samples were collected. A summary of the number and dates of samples collected for each phase of field work, and for each sampling medium, is presented in Table 3-1. The samples were submitted for laboratory analysis to determine the presence of volatile BTEX compounds, semi-volatile PAHs, TPH, metals, and pH. A summary list of the

analyses performed for each medium sampled is presented in Table 3-2. All first phase samples were shipped via Federal Express to the E & E Laboratory in Buffalo, New York, and the second phase samples were shipped to PDP Analytical Services in Houston, Texas. All analytical results are presented and evaluated in Section 4.

3.2 Soil Coring/Sampling

START used a Geoprobe™ hydraulic push sampler to initiate the first phase of field work in April and June 1998, to explore subsurface lithology, and determine the presence of site-related contaminants. Twenty-eight samples from nineteen 2-inch diameter soil cores were obtained to a maximum depth of 20 feet bgs within potential source areas. Samples were first logged by the field geologist, screened for the presence of volatile organic vapors using an HNu photoionization detector (PID), and transferred by hand from the acetate collection sleeves to the appropriate sample jars. Each borehole was sealed with bentonite pellets after sample collection.

In addition, during the second phase of field work in August 1998, a total of 27 hand-driven, slam-bar borings were advanced to obtain shallow subsurface soil samples and/or perched ground water samples. The location of all soil borings is shown in Figure 3-1. The Geoprobe™ soil cores and hand-driven samples were also used to interpret site-specific lithology, which is presented on boring logs in Appendix A. A summary of soil boring parameters for each location including total depth, depth to water if encountered, depth to bedrock if present, and observations of contamination, is presented in Table 3-3. The areal distribution of the depth to bedrock data is also depicted in Figure 3-2.

Fifty-five soil samples and six duplicates were collected from the subsurface (Table 3-2). The soil samples submitted to the laboratory were analyzed for BTEX compounds using EPA Method 8015B Mod., for PAHs using EPA Method 8310, for TPH using the Texas Natural Resource Conservation Commission (TNRCC) Method 1005, for metals using EPA Method 6010B, and for soil pH using EPA Method 9045C (Table 3-2). Soil sampling results are presented in Section 4.1.

3.3 Ground Water Sampling

Eight ground water samples and one duplicate were collected at the water table where encountered (Table 3-1). All ground water sample locations and the associated soil borings are depicted in Figure 3-3. Samples were obtained where possible from open soil borings using the

stainless steel or acetate soil sampling tubes as bailers. Samples were placed in the appropriate containers, and cooled to 4° Celsius. Ground water samples were submitted for laboratory analysis to determine the presence of BTEX compounds and TPH. Ground water sampling results are presented in Section 4.2.

3.4 Surface Water Sampling

Four surface water samples and one duplicate were collected near the water surface from the upstream (north) and downstream (south) ends of (b) (6) pond; and from the upstream and downstream ends of Tributary 2 at the property boundaries. All surface water sample locations are depicted in Figure 3-3. Samples were obtained directly in the appropriate containers, at or near the water surface. Samples were cooled to 4° Celsius and submitted to the laboratory for analysis of BTEX compounds and TPH (Table 3-2). Surface water sampling results are presented in Section 4.3.

3.5 Sediment Sampling

Two sediment samples were collected to fill a data gap in the ESI sampling program, and to evaluate the potential for contaminant migration from Pond 2 toward Sand Creek. Sediment samples were collected at the surface from depositional features in the drainage channel, using dedicated stainless steel sampling trowels. The sediment samples submitted to the laboratory were analyzed for BTEX, PAHs, TPH, metals, and pH (Table 3-2). Sediment sampling results are presented in Section 4.4.

3.6 HAZCAT Testing

START performed a series of simple field chemistry tests on one soil sample collected from the unvegetated area on the (b) (6) property, in the west central portion of the site. The tests are designed to identify the hazard category (HAZCAT) of unknown samples in the following classifications: solubility/specific gravity, acid/base, oxidizer, flammable, chlorinated hydrocarbon, cyanide, sulfide, and hazard class. The HAZCAT test results are presented in Section 4.5.

3.7 Global Positioning System and Total Station Survey

Geographic coordinates of all soil boring locations were determined by START by using a hand-held Global Positioning System (GPS) instrument operating in autonomous mode, based on the North American Datum-83, with accuracy estimated at +/- 50 feet circular error probable.

The accuracy of the GPS survey is not deemed appropriate for the location of sampling points which are located manually in Section 3 figures to an estimated accuracy of ± 20 feet circular error.

A preliminary land survey was conducted by START on August 8, 1998 using a Sokkia Set-4E Total Intelligent Station surveying instrument. The main purpose of the survey was to determine elevations; and northing and easting locations of the steep embankment area near sampling location SB05 and Tributary 2 relative to a site benchmark established at the SL&SF railroad crossing on Refinery Road. It was anticipated that cross-sectional views of the former tank berm and Tributary 2 stream bank would be required to evaluate the probable migration of hydrocarbon contamination in SB05 toward the stream. However, no contaminants were detected in the second phase soil borings designed to assess the expected subsurface migration pathway, and no further topographical evaluation is required in this vicinity.

Table 3-1

SUMMARY OF THE NUMBER OF SAMPLES COLLECTED
WILCOX REFINERY
BRISTOW, OKLAHOMA

Medium	Depth Range (inches, feet-bgs)	Number of Samples	Date(s) Sampled
Phase 1			
Geoprobe™ Soil	0 to 15 feet	28	4/27 - 6/4/98
Soil Duplicate	0 to 15 feet	3	6/1 - 6/3/98
Ground Water (GW)	2 to 16 feet	5	6/1 - 6/3/98
GW Duplicate	7 to 8 feet	1	6/3/98
Sediment	0 to 3 inches	2	4/28/98
Trip Blank	NA	2	6/2 - 6/3/98
Phase 2			
Slam-bar Soil	0 to 3 feet	16	8/4 - 8/6/98
Soil Duplicate	0 to 3 feet	1	8/6/98
JMC® Boring Soil	2 to 12 feet	11	8/4 - 8/6/98
Soil Duplicate	2 to 12 feet	2	8/5 - 8/6/98
Ground Water	6 to 8 feet	3	8/5 - 8/6/98
Surface Water (SW)	NA	4	8/4 - 8/6/98
SW Duplicate	NA	1	8/5/98
Trip Blank	NA	2	8/4 - 8/6/98
TOTAL		**81**	

Key:

bgs - below ground surface
NA - Not applicable

Table 3-2

SUMMARY OF THE ANALYTICAL PROGRAM
WILCOX REFINERY, BRISTOW, OKLAHOMA

Medium	Number of Samples[a]	BTEX[b] 8021B Mod.	TPH[c] 1005	PAHs[d] 8310	Metals[e] 6010B	pH[f] 9045C
Soil	61	X	X	X	X	X
Ground Water	9	X	X*			
Surface Water	5	X	X			
Sediment	2	X	X	X	X	X
Trip Blank	4	X				
TOTAL	**81**					

Key:

a - Includes all media, duplicates, and field quality control samples collected
b - Benzene, toluene, ethylbenzene, and xylenes by GC Method 8021B Modified
c - Total petroleum hydrocarbons by GC Method 1005 per TNRCC
d - Polycyclic aromatic hydrocarbons by HPLC Method 8310
e - 23 metals by ICP Method 6010B
f - Hydrogen ion concentration expressed in negative log units by Method 9045C
* - TPH was not analyzed in Sample GW08 due to low sample volume

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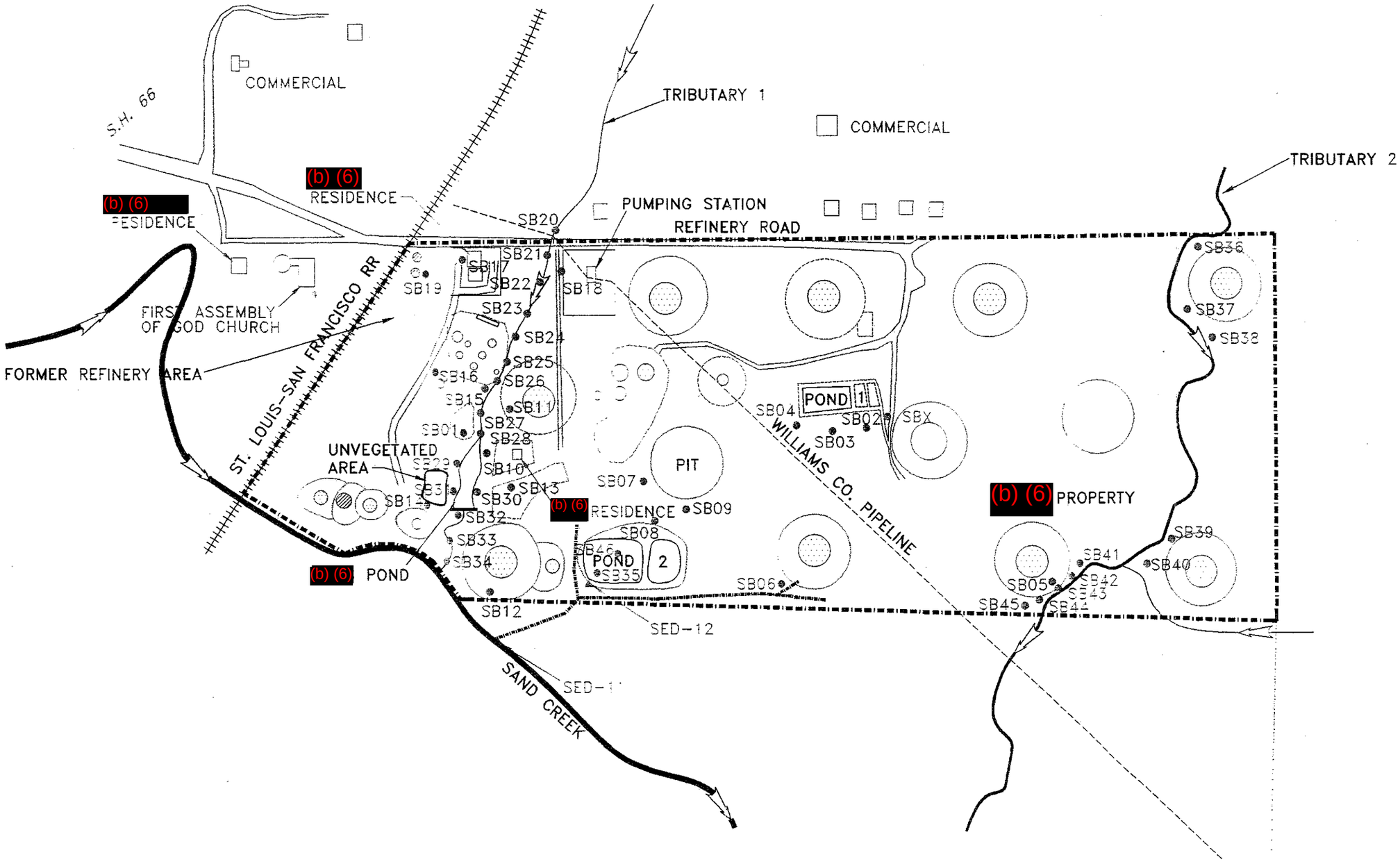

LEGEND

- FORMER TANK LOCATION
- CUT/LEVELED BERM
- BERM
- BUILDING
- EXISTING TANKS
- SITE BOUNDARY
- POND
- DRAINAGE DITCH
- SEDIMENT SAMPLE LOCATION
- SOIL BORING LOCATION
- DIRECTION OF FLOW

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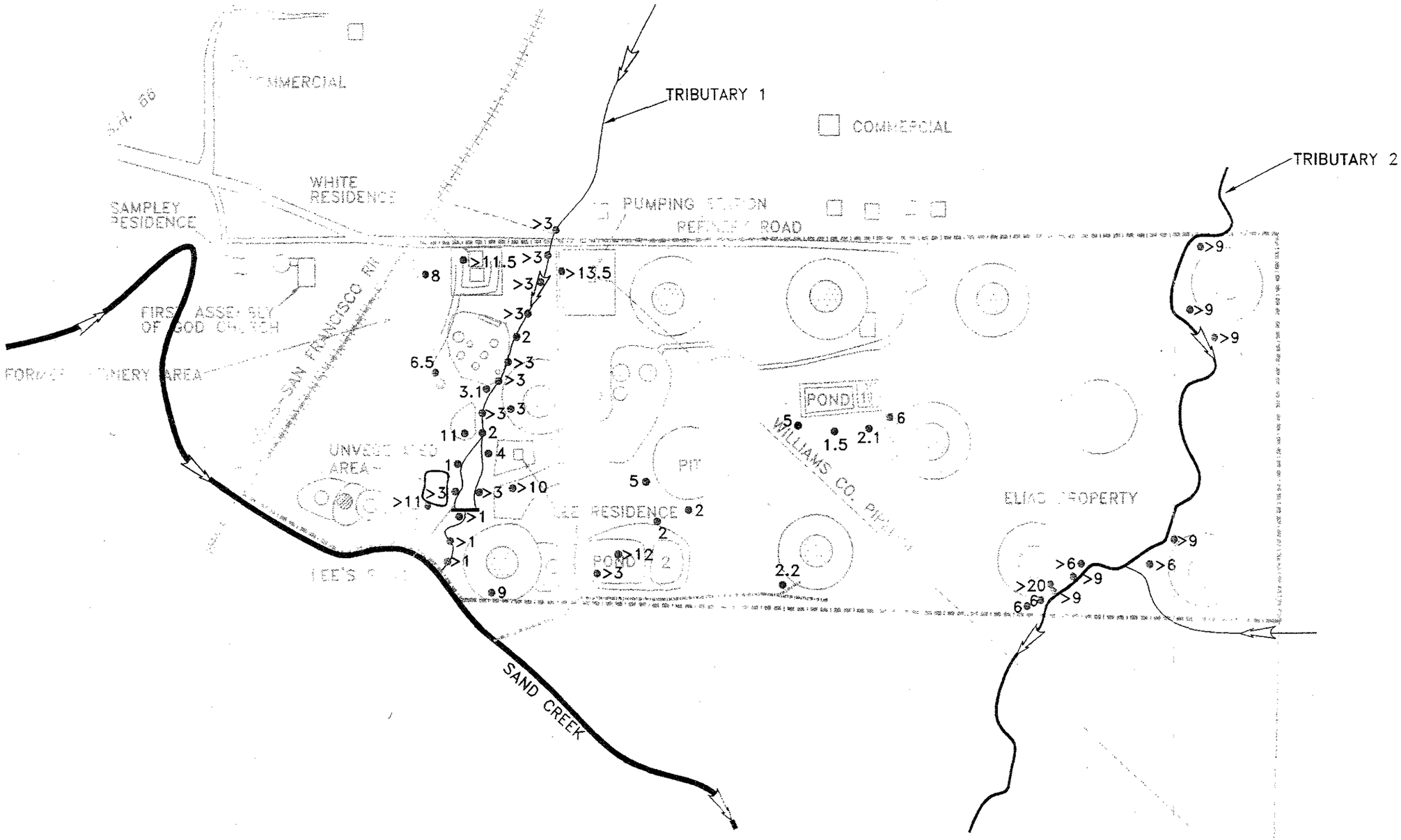
FIGURE 3-1 SOIL BORING AND SEDIMENT SAMPLE LOCATIONS
WILCOX REFINERY
BRISTOW, OKLAHOMA

TDD# S06-98-03-0009 Date: MARCH 31, 1999

PAN# 052601SFXX P.M.: T. BEER

BASE MAP SOURCE: ROY F. WESTON INC., ESI REPORT, MARCH, 1997, FROM ACE AERIAL PHOTO, 1966.



NOTES	LEGEND
8 – DEPTH TO BEDROCK IN FEET BELOW GRADE. >10 – BEDROCK NOT ENCOUNTERED. TOTAL DEPTH OF BORING SHOWN IN FEET BELOW GRADE.	SOIL BORING LOCATION DIRECTION OF FLOW

BASE MAP SOURCE: ROY F. WESTON INC., ESI REPORT, MARCH, 1997, FROM ACE AERIAL PHOTO, 1966.

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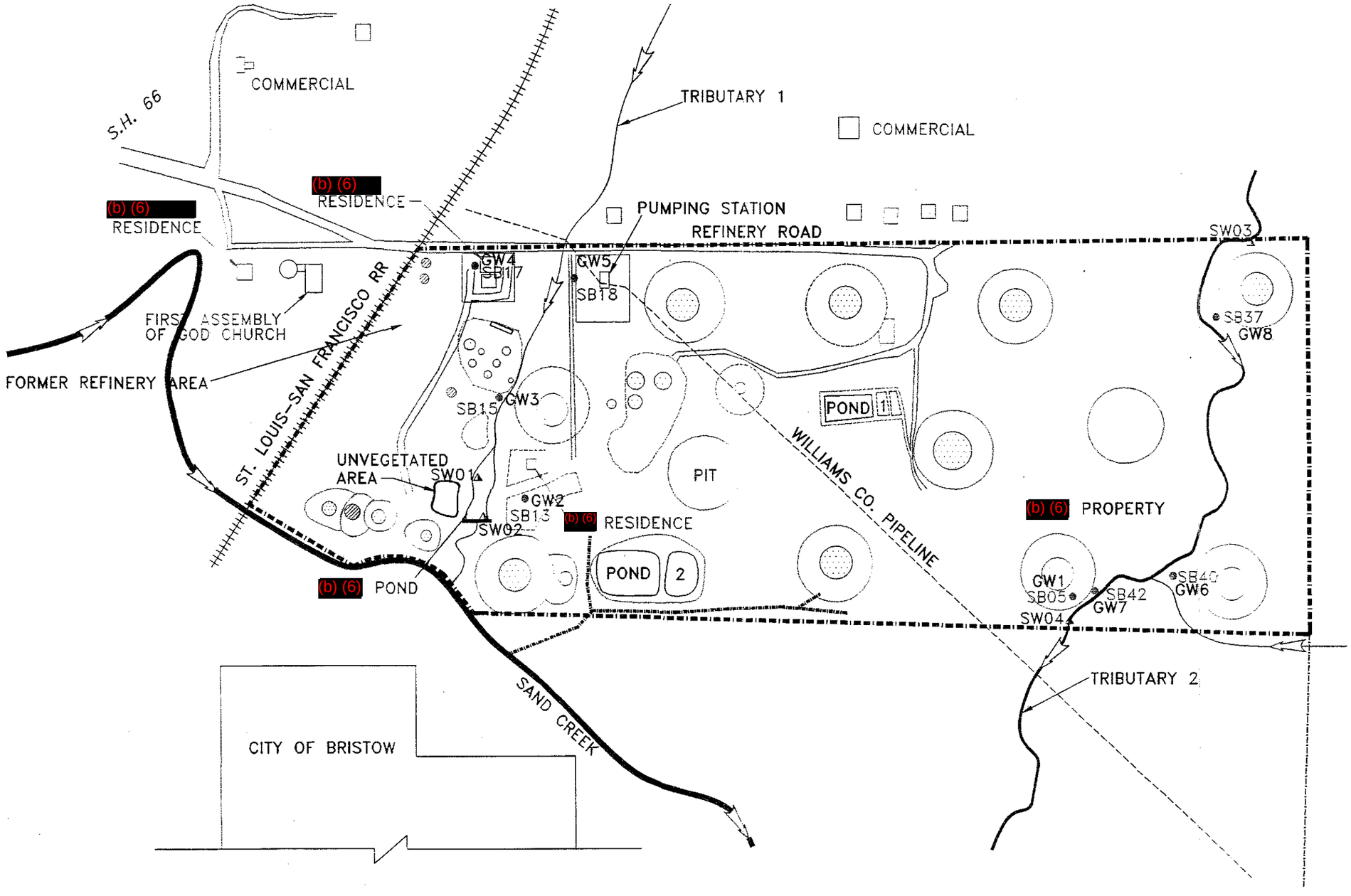
FIGURE 3-2 DEPTH TO BEDROCK IN SOIL BORINGS
WILCOX REFINERY
BRISTOW, OKLAHOMA

TDD# S06-98-03-0009	Date: MARCH 31, 1999
PAN# 052601SFXX	P.M.: T. BEER

ok2601-a.DWG 06 WH



LEGEND

- FORMER TANK LOCATION
- CUT/LEVELED BERM
- BERM
- RESIDENCE
- EXISTING TANKS
- SITE BOUNDARY
- POND
- GW1 GROUND WATER SAMPLE
- DRAINAGE DITCH
- SOIL BORING LOCATION
- SW04 SURFACE WATER SAMPLE
- DIRECTION OF FLOW

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FIGURE 3-3 WATER SAMPLE LOCATIONS
WILCOX REFINERY
BRISTOW, OKLAHOMA

TDD# S06-98-03-0009	Date: MARCH 31, 1999
PAN# 052601SFXX	P.M.: T. BEER

BASE MAP SOURCE: ROY F. WESTON INC., ESI REPORT, MARCH, 1997, FROM ACE AERIAL PHOTO, 1966.

Table 3-3

SOIL BORING PARAMETERS
WILCOX REFINERY, BRISTOW, OKLAHOMA

Soil Boring Number	Total Depth (feet)	Depth to Water (feet)	Depth to Bedrock (feet)	Field Observation of Contamination
SB-X	6.0	0.0*	6.0	None observed
SB-1	11.0	0.0*	11.0	Black staining with strong petroleum odor noted from 0.0 to 10 feet bgs
SB-2	2.1	Not encountered	2.1	None observed
SB-3	1.5	Not encountered	1.5	None observed
SB-4	5.0	Not encountered	5.0	Trace dark petroleum staining with slight petroleum odor at 4-feet bgs
SB-5	20.0	15.5	Not encountered	Petroleum odor throughout, trace oil product (0-3'), slight staining (4-8'), sheen on groundwater
SB-6	2.2	Not encountered	2.2	None observed
SB-7	5.0	Not encountered	5.0	None observed
SB-8	2.0	Not encountered	2.0	None observed
SB-9	2.2	Not encountered	2.0	None observed
SB-10	4.3	Not encountered	4.0	None observed
SB-11	3.0	Not encountered	3.0	None observed
SB-12	9.0	8.9	9.0	None observed
SB-13	10.0	8.0	Not encountered	Slight to strong petroleum odor noted from 4.0 to 7.5 feet bgs
SB-14	11.0	4.5	Not encountered	Sulfurous, anaerobic decay odor throughout
SB-15	3.1	1.0	3.1	Fill material throughout, consisting of black cinder or ash
SB-16	6.5	4.0	6.5	Petroleum odor noted from 1.1 to 6.1 feet bgs
SB-17	11.5	6.3	Not encountered	Petroleum odor noted from 4.0 to 6.3 feet bgs
SB-18	13.5	8.0	Not encountered	Old gasoline odor throughout, free-phase petroleum product on groundwater
SB-19	8.0	Not encountered	8.0	Petroleum odor and staining noted from 0.0 to 5.2 feet bgs
SB-20	3.0	Not encountered	Not encountered	None observed
SB-21	3.0	Not encountered	Not encountered	None observed
SB-22	3.0	Not encountered	Not encountered	None observed
SB-23	3.0	Not encountered	Not encountered	None observed
SB-24	2.0	Not encountered	2.0	Petroleum odor and staining noted at 2.0 feet bgs
SB-25	3.0	Not encountered	Not encountered	None observed
SB-26	3.0	Not encountered	Not encountered	None observed
SB-27	3.0	Not encountered	Not encountered	None observed
SB-28	2.0	Not encountered	Not encountered	None observed
SB-29	1.0	Not encountered	Not encountered	None observed
SB-30	3.0	Not encountered	Not encountered	Petroleum odor and staining noted 0.0 to 1 feet bgs
SB-31	3.0	Not encountered	Not encountered	Petroleum odor and staining noted 0.0 to 1 feet bgs
SB-32	1.0	Wet throughout	Not encountered	Petroleum odor and staining noted 0.0 to 1 feet bgs
SB-33	1.0	Wet throughout	Not encountered	Petroleum odor and staining noted 0.0 to 1 feet bgs
SB-34	1.0	Wet throughout	Not encountered	Petroleum odor and staining noted 0.0 to 1 feet bgs
SB-35	3.0	Not encountered	Not encountered	Strong petroleum odor from 0 to 3 feet bgs
SB-36	9.0	6.5	Not encountered	Slight petroleum odor noted from 0 to 1 feet bgs
SB-37	9.0	6.5	Not encountered	None observed
SB-38	9.0	1.0	Not encountered	None observed
SB-39	9.0	1.0	Not encountered	None observed
SB-40	6.0	3.5	Not encountered	None observed
SB-41	6.0	2.5	Not encountered	None observed
SB-42	6.0	2.5	Not encountered	None observed
SB-43	9.0	6.5	Not encountered	None observed
SB-44	6.0	4.5	Not encountered	None observed
SB-45	9.0	1.0	Not encountered	None observed
SB-46	12.0	Not encountered	Not encountered	Strong petroleum odor and staining from 0.0 to 12.0 feet bgs

Key:
* - Boring was completed on April 27, 1998. Due to 4 inches of rainfall on April 26, the ground surface was saturated
bgs - Below ground surface

4 Nature and Extent of Spill Impact

The nature and extent of the spill impact at Wilcox refinery was assessed using field and analytical laboratory data. A summary of analytical results is discussed below by sampling media. Table 4-1 presents organic analytical results for sediment and subsurface soil samples, Table 4-2 presents inorganic analytical results for sediment and subsurface soil samples, and Table 4-3 presents analytical results for ground water samples. Analytical results for soil are reported as milligrams per kilogram (mg/kg), and all ground water data are presented in milligrams per liter (mg/L). The complete analytical data package from the sampling program at Wilcox is presented in Appendix I. The overall analytical data quality is assessed in Section 4.6 and summarized in Table 4-4. A preliminary estimate of the waste quantity on site based on a spatial evaluation of the analytical data is presented in Section 4.7, and summarized in Table 4-5.

The soil, ground water, surface water, and sediment analytical data were reviewed and qualified under U.S. EPA data validation guidelines (U.S. EPA 1994a, 1994b). Data qualifiers are assigned in the data tables when necessary, to indicate that caution should be exercised when using these results. The significance of detected analyte concentrations for each medium is evaluated in Section 4.6, based on comparison with selected chemical-specific regulatory criteria. For data presentation purposes, only site data greater than regulatory screening levels to be considered (TBC) materials for any organic sample (Table 5-1) or '20 times' toxicity characteristic leaching procedure (TCLP) inorganic criteria (Table 5-2), are presented. Further discussion of organic and inorganic TBCs can be found in Section 5.

4.1 Soil Analytical Results

A total of 55 soil samples were collected from 46 soil borings and analyzed for BTEX compounds, TPH, and PAHs (organics); and for metals and pH (inorganics). The soil sampling results are presented below for each type of analysis.

4.1.1 Organics

Twenty-five organic compounds were detected in site soil, including all four BTEX compounds: benzene, toluene, ethylbenzene, and xylenes (Table 4-2). Of these compounds, xylenes (total) was detected most frequently (12 of 55 samples). Ethylbenzene and toluene were each detected in 11 of 55 samples, and benzene was detected in seven of 55 samples. The areal distribution of BTEX compounds in soil at concentrations greater than screening levels is shown in Figure 4-1. The maximum detected benzene concentration is 2.2 mg/kg from SB16 at 5 to 6 feet bgs. The maximum detected concentrations for ethylbenzene (670 mg/kg), toluene (410 mg/kg), and xylenes (2,700 mg/kg) were from SB01 at 0 to 0.5 feet bgs.

Seventeen of 18 PAHs analyzed for were detected, with acenaphthylene not detected. Phenanthrene was detected most frequently, it was present in 26 of 55 samples. Benzo(a)-anthracene was detected 23 times, and benzo(b)fluoranthene and detected 21 times (Table 4-1). The areal distribution of PAHs in soil at concentrations greater than screening levels is shown in Figure 4-1. The maximum concentrations for all PAHs detected occurred in SB15 at 0 to 1 foot bgs. Elevated concentrations of most PAHs were also noted in SB34 at 0 to 1 foot bgs.

Total petroleum hydrocarbons (TPH) were detected in 15 of 55 samples (Table 4-1). The areal distribution of TPH in soil at concentrations greater than screening levels is shown in Figure 4-1. The maximum detected TPH concentration is 280,000 mg/kg in SB15 at 0 to 1 foot bgs. Elevated concentrations of TPH were also noted at soil boring locations SB01, SB05, SB14, SB16, SB17, SB18, SB19, SB20, SB24, SB33, and SB34. Elevated BTEX and PAH results often occur significantly at locations with elevated TPH concentrations.

4.1.2 Inorganics

Metals are naturally occurring elements in soils. For screening the significance of results, metal concentrations detected in on-site soil samples were compared to a factor of "20 times TCLP criteria" based on the extraction methodology of the toxicity characteristic leaching procedure (TCLP) (40 CFR 261). For presentation purposes, metal concentrations exceeding the TCLP based screening factor are highlighted in Table 4-2, and presented spatially in Figure 4-2.

Twenty-one of the 23 metals analyzed were detected in site soil, four of which were detected in all 55 samples analyzed (aluminum, calcium, iron, and manganese). Barium, chromium, potassium, and zinc were each detected in 54 samples. Based on lead as the key indicator metal of concern at refinery sites, the maximum lead concentration is 15,200 mg/kg in sample SB35 at 0 to 3 feet bgs in Pond 2. Elevated lead concentrations are also present

throughout the Tributary 1 stream bed; however, the maximum concentration along this pathway, 1,960 mg/kg, occurs in the off-site, upstream sample at SB20, from 0 to 3 feet bgs. This indicates that upstream sources on the Ohio Oil refinery site and multiple on-site sources (Figure 2-4) may have contributed to documented lead impacts in the Tributary 1 stream channel on the Wilcox site (Figure 4-2).

Soil pH is a measure of acidity and an indicator of unnatural site conditions. Refinery wastes can be extremely acidic due to the presence of sulfur compounds, and oil field brines and drilling muds are typically caustic. A neutral pH is 7, with extreme acid conditions being less than 2, and elevated caustic conditions greater than 12. The results from pH testing of soil samples are presented in Table 4-2. A total of seven soil samples from different borings have a pH less than 4, with no pH results greater than 10. The two lowest values, 2.3 in SB08 at 1 to 2 feet bgs, and 2.8 in SB10 at 3 to 4 feet bgs, appear to be unnaturally acidic conditions. Potential sources exist upgradient at each location: the "Oily Waste Pit" near SB08, and backfilled ponds beneath and south of the (b) (6) residence near SB10 (see Figures 2-4 and 3-1).

4.2 Ground Water Analytical Results

A total of eight ground water samples and one duplicate were collected where ground water was encountered in soil borings, and analyzed for BTEX compounds and TPH. The ground water sampling results are presented below for each type of analysis.

4.2.1 Benzene, Toluene, Ethylbenzene, and Xylenes

A summary of BTEX compounds detected in ground water samples at the Wilcox site is presented in Table 4-3, and the areal distribution of contamination is depicted in Figure 4-3. Ethylbenzene was detected most often, in five of eight samples. Xylenes are present in four samples, benzene was detected in two samples, and toluene was detected in one of the eight samples. The maximum detected concentrations of benzene (8.9 mg/L), ethylbenzene (3.3 mg/L), and xylenes (9.1 mg/L) were in sample GW5 from SB18 near the fenced Sun Oil Company property. Note that a thin petroleum product layer was observed in this sample vial.

4.2.2 Total Petroleum Hydrocarbons

A summary of TPH carbon ranges detected in ground water samples at the Wilcox site is presented in Table 4-3, and the areal distribution of contamination is depicted in Figure 4-3. TPH was not analyzed in sample GW8 due to the low sample volume present. TPH in both the gasoline carbon range (C6-C10) and kerosene/diesel/lube oil carbon range (C10-C28) was

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detected in samples GW1, GW2, and GW5. The maximum detected concentrations of C6-C10 hydrocarbons (3,300 mg/L), and C10-C28 hydrocarbons (5,900 mg/L), were in sample GW5 from SB18, coinciding with the maximum detections of BTEX compounds. The elevated concentration of TPH in GW4 at SB17 is also significant because of its location in the fenced yard of the (b) (6) residence (Figure 4-3).

4.3 Surface Water Analytical Results

A total of four surface water samples that were most representative of upstream versus downstream conditions were collected from available locations in Tributaries 1 and 2. Due to low flow conditions, samples could only be obtained from (b) (6) Pond on Tributary 1, and isolated pools in Tributary 2. Each sample was analyzed for BTEX compounds and TPH.

No BTEX compounds or TPH were detected in site surface water samples. Detection limits and the analytical data package are presented in Appendix I.

4.4 Sediment Analytical Results

Two sediment samples were collected to assess the potential for contaminant migration from Pond 2 to Sand Creek via the surface water runoff pathway. The sediment samples were analyzed for BTEX compounds, TPH, and PAHs (organics) and for metals and pH (inorganics). It should be noted that the subsurface soil samples identified as SB20 to SB34 were collected from the dry creek bed of Tributary 1, and should be considered along with all sediment data in the evaluation of site impacts to the surface water migration pathway, and waters of the United States. The sediment sampling results from samples SED11 and SED12 are presented below for each type of analysis.

4.4.1 Organics

No BTEX compounds or TPH were detected in site sediment samples. Detection limits are specified in Table 4-1 and in the analytical data package, presented in Appendix I.

Seven of 18 PAHs analyzed for were detected in site sediment. Benzo(a)anthracene, benzo(a)pyrene, and pyrene were detected in each sample; and benzo(b)flouranthene, chrysene, fluoranthene, and phenanthrene were each detected once (Table 4-1). The highest level of PAH detected was pyrene, which was detected in SED11 at 0.41 mg/kg and in SED12 at 0.12 mg/kg. No pattern in the concentration of PAHs in the upstream (SED12) versus the downstream (SED11) sample could be discerned.

4.4.2 Inorganics

Metals are naturally occurring elements in sediment. Antimony, beryllium, cadmium, mercury, selenium, silver, and thallium were not detected in the site samples. The analytical results for metals detected in sediment samples are summarized in Table 4-2. Fifteen of the 23 metals analyzed for were detected in site sediment, 13 of which were detected in both samples analyzed. Based on lead as the key indicator metal of concern at refinery sites, the concentrations of lead in sediment are 32.4 mg/kg in SED11 at Sand Creek, and 16.7 mg/kg in SED12 at Pond 2. As a reference, these concentrations are significantly lower than the maximum lead concentration for the Wilcox site (15,200 mg/kg), which was collected upstream in Pond 2 soil at SB35 (see Section 4.1.2). The sediment samples from the Pond 2 flow path do not show elevated concentrations from Pond 2 metals contamination. There was no discernable pattern in the concentration of metals in the upstream (SED12) versus the downstream (SED11) sample.

The pH result of 7.1 for each sediment sample is neutral with respect to acidic or basic site conditions. By comparison, subsurface soil samples collected from Pond 2 have pH levels of 5.1 and 6.2.

4.5 HAZCAT Result

One sample of a solid waste from the unvegetated area on the (b) (6) property was subjected to HAZCAT field testing. No other waste sources were deemed appropriate for testing due to the oily nature of the matrices or adequate waste characterization from the ESI sampling program.

The following list indicates the qualitative HAZCAT test tube results for the waste sample:

- Sample Description: grey, granular, solid waste, fertilizer-type odor,
- Specific Gravity: >1,
- Water Reactivity: Negative,
- Solubility: Sparingly soluble,
- pH: 5.5,
- Presence of Oxidizers: Negative,
- Sulfide: Not Applicable if pH <7,
- Cyanide: Not Applicable if pH <7,

- Chlorinated Hydrocarbons - Copper Wire Test: Negative,
- Chlorinated Hydrocarbons - PCB Test Kit: Positive, greater than 50 ppm, and
- Flammability: Negative,

The only significant positive result from the HAZCAT testing was from the polychlorinated biphenyl (PCB) test kit. A previous sample taken from the unvegetated area during the ESI revealed non-detects for all EPA target analyte list (TAL) pesticides and PCBs. This positive HAZCAT test result for PCBs appears to be a false positive result due to the following possible interferences identified in the field test kit manufacturer's instructions: excess moisture, inorganic chlorides, or the presence of other chlorinated organic compounds (i.e., solvents, pesticides).

4.6 Data Quality Assessment

Data quality assessment is a qualitative and quantitative review performed on the analytical results generated from the site sampling program to establish the usability of the data. Initially, all START laboratory data were validated and qualified according to EPA data review procedures (U.S. EPA 1994a, 1994b). Data qualifiers are presented in the appropriate data tables in this section and explained in detail in the data validation reports in Appendix J. Quality of the validated data was assessed in terms of precision, accuracy, representativeness, comparability, and completeness (PARCC) parameters, in accordance with EPA guidance (U.S. EPA 1990). A summary of the methodology and results from the evaluation of each PARCC parameter is presented below, and summarized in Appendix J.

4.6.1 Precision

Precision is a quantitative measure of the variability between duplicate samples. Precision is expressed as the relative percent difference (RPD) in concentration between duplicate pairs of field duplicates, matrix spikes (MS), and laboratory duplicates.

Although some precision data results are outside QC criteria, the overall usability of the qualified data is not compromised. The instances where data precision did not meet QC criteria are attributable to interferents in the matrix, high concentrations of target compounds, or relatively few data points to determine correlations and conclusions.

4.6.2 Accuracy

Accuracy is a quantitative measure of the recoverability of known amounts ("spikes") of target compounds for each analytical method. Accuracy is reported as the percent recovery (%R) of the known spike concentration minus the original sample result for MS, surrogate recoveries, and laboratory control samples (LCS).

Data for five metals (antimony, beryllium, arsenic, cadmium, and cobalt) in 10 samples were unusable (R) due to poor recoveries in one MS sample. Post spike recoveries were acceptable, indicating a possible digestion problem in one batch of samples at the laboratory. Discretion should be used when evaluating the site impact of these target compounds. With the exception of the unusable metals data, the overall usability of the data is acceptable with respect to accuracy. Other instances where data fail to meet accuracy QC criteria are considered isolated and not indicative of overall poor method performance.

4.6.3 Representativeness

Representativeness is a qualitative evaluation of the extent to which the analytical data reflect actual site conditions. Acceptable representativeness is achieved by proper sampling and sample management procedures.

The overall usability of the data is acceptable with respect to representativeness. Limited qualifications were assigned to the data for calibration or preparation blank contaminants, exceedence of serial dilution criteria, and internal standard deficiencies. In instances where data qualifiers are applied, some discretion should be used when evaluating potential site impacts of the data.

4.6.4 Comparability

Comparability is a qualitative parameter that expresses the confidence with which one data set can be compared to another. Analytical comparability is considered acceptable for this investigation because:

- The investigation consistently utilized the same analytical laboratory, sample preparation routine, and analytical methods (within each phase of work);
- The analytical results for each analysis are reported with consistent detection limits and units of measure; and
- Soil/sediment results are reported on a dry weight basis, allowing for comparison between samples and with regulatory criteria.

4.6.5 Completeness

Completeness is a measure of the amount of usable data resulting from the analytical program at the site. Analytical completeness is defined as the percentage of acceptable data points. Only unusable data (qualified "R" during data validation) is excluded when assessing compliance with the completeness goal of 90% (U.S. EPA 1990). Completeness is calculated per analytical method, but is also evaluated by individual analyte per matrix in Table 4-4.

For the Wilcox refinery site assessment data set, the analytical completeness for BTEX and PAH testing is 100%. A total of 55 metals data points were determined to be unusable due to laboratory data quality problems, resulting in an overall acceptable completeness of 96%. However, antimony, arsenic, beryllium, cadmium, and cobalt in soil did not meet the completeness goal of 90% and care should be used when assessing the impact of these individual metals at the site (Table 4-4).

One TPH in water sample was proposed but not analyzed due to low sample volume, resulting in an overall method completeness of 98.5%. However, TPH in water did not meet the completeness goal of 90% and care should be taken when evaluating this data set.

A summary of the quantitative data quality assessment criteria used to evaluate site data (i.e., precision, accuracy, representativeness, and completeness) and a comparison with actual data quality achieved for the project is presented in Appendix J.

4.7 Waste Quantity

During planning of the sampling program for this investigation, a list of potential waste source areas was developed based on the results of the previous ESI, and from START visual observations during initial site visits. Then, from the analytical results in each source area, and with the interpretation of source-specific soil boring logs and reasonable assumptions, the volume of contaminated material in each source area was estimated. A summary list of waste sources and estimated waste quantities is presented in Table 4-5. At this time, it is estimated that a minimum of approximately 73,000 cubic yards of solid waste (contaminated soil, coking cinders waste, tarry waste, etc.), and 2,960 gallons of liquid waste (tank bottom sludge, oily liquid, and product in existing ASTs) exists at the Wilcox site.

The liquid waste volume referred to in the last Table 4-5 entry for the 'Lower reaches of Tributary 1,' is for a brown, degraded, oily liquid entering Tributary 1 via a buried pipeline from the (b) (6) property. During the low flow conditions observed on August 5, 1998, the volume of flow was estimated at less than 1 gallon per minute. Historical effects from this and other sources have visibly stained the stream bed black for at least 250 feet downstream. During this

dry period, no flow from Tributary 1 entered Sand Creek, approximately 300 feet south of the pipeline source. Note that the source inventory may be incomplete, the estimated waste quantity at some identified potential source areas remains unknown, and the liquid waste quantity does not include known areas of contaminated, shallow ground water at the site.

Table 4-1

ORGANIC ANALYTICAL RESULTS IN SEDIMENT AND SOIL
WILCOX REFINERY, BRISTOW, OKLAHOMA

Sample Location Depth (ft)	SED11 0-1	SED12 0-1	SB01 0-0.5	SB01 10-11	SB02 1-2	SB03 1.5-2	SB04 4-5	SB05 1-2	SB05 4-5
Analyte									
Volatiles (BTEX) - mg/kg									
Benzene	<0.00075	<0.00074	<4.3	**0.017**	<0.0021	<0.0021	<0.0021	<0.0023	**0.040**
Ethylbenzene	<0.00088	<0.0011	**670**	**0.25**	<0.0021	<0.0021	<0.0021	<0.0023	**0.84**
Toluene	<0.0011	<0.00086	**410**	**0.23**	<0.0021	<0.0021	<0.0021	**0.034**	**0.018**
Xylene (total)	<0.0025	<0.0025	**2,600**	**0.76**	<0.0021	<0.0021	<0.0021	<0.0023	**1.1**
Semi-Volatiles (PAHs) - mg/kg									
Acenaphthene	<0.25	<0.25	<2.2	<0.24	<0.21	<0.21	<0.21	<1.1	<2.5
Acenaphthylene	<0.25	<0.25	<2.2	<0.24	<0.21	<0.21	<0.21	<1.1	<2.5
Anthracene	<0.025	<0.025	<0.22	<0.024	<0.021	<0.021	<0.021	<0.11	<0.25
Benzo(a)anthracene	**0.049**	**0.033**	**0.57**	<0.024	<0.021	<0.021	<0.021	**0.14**	**0.67**
Benzo(b)fluoranthene	<0.025	**0.095**	**1.1**	<0.024	<0.021	<0.021	<0.021	**0.080 JK**	**0.25**
Benzo(k)fluoranthene	<0.025	<0.025	**0.35**	<0.024	<0.021	<0.021	<0.021	**0.091 JK**	**0.17 JK**
Benzo(a)pyrene	**0.041**	**0.041**	**1.4**	<0.024	<0.021	<0.021	<0.021	**0.11**	**0.20 JK**
Benzo(ghi)perylene	<0.062	<0.062	<0.54	<0.060	<0.053	<0.053	<0.053	<0.28	<0.62
Chrysene	**0.064**	<0.025	**1.4**	<0.024	<0.021	<0.021	<0.021	<0.11	<0.25
Dibenzo(a,h)anthracene	<0.062	<0.062	<0.54	<0.060	<0.053	<0.053	<0.053	<0.28	<0.62
Fluoranthene	**0.089**	<0.062	**5.1**	**0.073**	<0.053	<0.053	<0.053	**0.35**	**2.5**
Fluorene	<0.025	<0.025	<0.22	<0.024	<0.021	<0.021	<0.021	<0.11	<0.25
Indeno(1,2,3-cd)pyrene	<0.025	<0.025	<0.22	<0.024	<0.021	<0.021	<0.021	<0.11	<0.25
1-Methylnaphthalene	<0.25	<0.25	<2.2	<0.24	<0.21	<0.21	<0.21	<1.1	**4.6**
2-Methylnaphthalene	<0.25	<0.25	**3.2**	**0.34**	<0.21	<0.21	<0.21	<1.1	**5.3**
Naphthalene	<0.25	<0.25	<2.2	<0.24	<0.21	<0.21	<0.21	<1.1	<2.5
Phenanthrene	**0.040**	<0.025	**1.9**	**0.052**	<0.021	<0.021	<0.021	<0.11	**1.2**
Pyrene	**0.410**	**0.12**	**7**	**0.14**	<0.053	<0.053	<0.053	<0.28	<0.62
TPH - mg/kg									
C6 - C10 Hydrocarbons	<31	<31	**2,600**	**370**	<53	<53	<53	<57	**700**
>C10 - C28 Hydrocarbons	<31	<31	**1,500**	**120**	<53	<53	<53	<57	**2,600**
TPH C6 - C28 Hydrocarbons	<62	<62	**4,100**	**490**	<53	<53	<53	<57	**3,400**

Key at end of table.

Table 4-1 (cont.)

ORGANIC ANALYTICAL RESULTS IN SEDIMENT AND SOIL
WILCOX REFINERY, BRISTOW, OKLAHOMA

Sample Location Depth (ft)	SB05 14-15	SB06 1-2	SB07 4-5	SB07D 4-5	SB08 1-2	SB09 1-2	SB10 3-4	SB11 2-3	SB12 1-2
Analyte									
Volatiles (BTEX) - mg/kg									
Benzene	**0.0043**	<0.0023	<0.0023	<0.0022	<0.0022	<0.0023	<0.0022	<0.0024	<0.0023
Ethylbenzene	**0.023**	<0.0023	<0.0023	<0.0022	<0.0022	<0.0023	<0.0022	<0.0024	<0.0023
Toluene	<0.0024	<0.0023	<0.0023	<0.0022	<0.0022	<0.0023	<0.0022	<0.0024	<0.0023
Xylene (total)	**0.078**	<0.0023	<0.0023	<0.0022	<0.0022	<0.0023	<0.0022	<0.0024	<0.0023
Semi-Volatiles (PAHs) - mg/kg									
Acenaphthene	<1.2	<0.23	<0.23	<0.22	<0.22	<0.23	<0.22	<0.24	<0.23
Acenaphthylene	<1.2	<0.23	<0.23	<0.22	<0.22	<0.23	<0.22	<0.24	<0.23
Anthracene	<0.12	<0.023	<0.023	<0.022	<0.022	<0.023	<0.022	<0.024	<0.023
Benzo(a)anthracene	**0.43**	**0.015 JK**	<0.023	**0.031**	<0.022	**0.039**	<0.022	**0.072**	<0.023
Benzo(b)fluoranthene	**0.15 JK**	**0.025**	<0.023	**0.064**	<0.022	**0.016 JK**	<0.022	**0.088**	<0.023
Benzo(k)fluoranthene	**0.12 JK**	<0.023	<0.023	**0.017 JK**	<0.022	**0.024**	<0.022	**0.059**	<0.023
Benzo(a)pyrene	**0.15**	**0.031**	<0.023	**0.07**	<0.022	**0.044**	<0.022	**0.11**	<0.023
Benzo(ghi)perylene	<0.30	**0.028 JK**	<0.057	<0.056	<0.054	<0.057	<0.056	**0.039 JK**	<0.057
Chrysene	**0.13 JK**	**0.025**	<0.023	<0.022	<0.022	**0.056**	<0.022	**0.12**	<0.023
Dibenzo(a,h)anthracene	<0.30	<0.057	<0.057	<0.056	<0.054	<0.057	<0.056	<0.059	<0.057
Fluoranthene	**1.5 JK**	**0.066**	<0.057	<0.056	<0.054	**0.061**	<0.056	**0.14**	<0.057
Fluorene	**0.12**	<0.023	<0.023	<0.022	<0.022	<0.023	<0.022	<0.024	<0.023
Indeno(1,2,3-cd)pyrene	<0.12	<0.023	<0.023	<0.022	<0.022	<0.023	<0.022	**0.028**	<0.023
1-Methylnaphthalene	**1.8**	<0.23	<0.23	<0.22	<0.22	<0.23	<0.22	<0.24	<0.23
2-Methylnaphthalene	**2.3**	<0.23	<0.23	<0.22	<0.22	<0.23	<0.22	<0.24	<0.23
Naphthalene	<1.2	<0.23	<0.23	<0.22	<0.22	<0.23	<0.22	<0.24	<0.23
Phenanthrene	**0.74**	**0.031**	<0.023	<0.022	<0.022	**0.068**	<0.022	**0.042**	<0.023
Pyrene	<0.30	<0.057	<0.057	**0.084**	<0.054	<0.057	<0.056	**0.12**	<0.057
TPH - mg/kg									
C6 - C10 Hydrocarbons	**260**	<57	<57	<56	<54	<57	<56	<59	<57
>C10 - C28 Hydrocarbons	**730**	<57	<57	<56	<54	<57	<56	<59	<57
TPH C6 - C28 Hydrocarbons	**990**	<57	<57	<56	<54	<57	<56	<59	<57

Key at end of table.

Table 4-1 (cont.)

ORGANIC ANALYTICAL RESULTS IN SEDIMENT AND SOIL
WILCOX REFINERY, BRISTOW, OKLAHOMA

Sample Location Depth (ft)	SB12 8-9	SB13 1-2	SB13 6.5-7.5	SB13D 6.5-7.5	SB14 1-2	SB14 5-6	SB15 0-1	SB16 5-6	SB17 1-2
Analyte									
Volatiles (BTEX) - mg/kg									
Benzene	<0.0023	<0.0022	<0.012	<0.011	<0.011	<0.09	**0.31**	**2.2 JH**	<0.0022
Ethylbenzene	<0.0023	<0.0022	<0.012	**0.023**	<0.011	<0.11	**0.95**	**1.6 JH**	<0.0022
Toluene	<0.0023	<0.0022	<0.012	<0.011	<0.011	**0.26**	**0.65**	**3.0 JH**	<0.0022
Xylene (total)	<0.0023	<0.0022	**0.013**	**0.091**	<0.011	<0.30	**9.8**	**3.5 JH**	<0.0022
Semi-Volatiles (PAHs) - mg/kg									
Acenaphthene	<0.23	<0.22	<0.23	<0.23	<0.23	<0.24	<2500	<12	<0.22
Acenaphthylene	<0.23	<0.22	<0.23	<0.23	<0.23	<0.24	<2500	<12	<0.22
Anthracene	<0.023	<0.022	<0.023	<0.023	<0.023	<0.024	**700 JK**	**1.5**	<0.022
Benzo(a)anthracene	<0.023	**0.021 JK**	<0.023	<0.023	**0.10**	**0.012 JK**	**2,800**	**3.0**	**0.0049 JK**
Benzo(b)fluoranthene	<0.023	**0.056**	<0.023	<0.023	**0.0088 JK**	<0.024	**320 JK**	**0.72 JK**	<0.022
Benzo(k)fluoranthene	<0.023	**0.018 JK**	<0.023	<0.023	<0.023	<0.024	**580**	**1.2 JK**	<0.022
Benzo(a)pyrene	<0.023	**0.074**	<0.023	<0.023	<0.023	<0.024	**920**	**2.0**	**0.037**
Benzo(ghi)perylene	<0.058	**0.04 JK**	<0.058	<0.057	<0.057	<0.06	<620	<3.0	<0.056
Chrysene	<0.023	**0.043**	<0.023	<0.023	<0.023	<0.024	**2,800**	<1.2	<0.022
Dibenzo(a,h)anthracene	<0.058	<0.056	<0.058	<0.057	<0.057	<0.06	<620	<3.0	<0.056
Fluoranthene	<0.058	**0.076**	<0.058	<0.057	**0.65**	<0.06	**6,000**	**16**	<0.056
Fluorene	<0.023	<0.022	<0.023	<0.023	<0.023	<0.024	**540**	**3.5**	<0.022
Indeno(1,2,3-cd)pyrene	<0.023	**0.027**	<0.023	<0.023	<0.023	<0.024	<250	<1.2	<0.022
1-Methylnaphthalene	<0.23	<0.22	<0.23	<0.23	<0.23	**0.24**	<2,500	**17**	<0.22
2-Methylnaphthalene	<0.23	<0.22	<0.23	<0.23	**2.3**	<0.24	**7,000**	**28**	<0.22
Naphthalene	<0.23	<0.22	<0.23	<0.23	<0.23	<0.24	<2500	<12	<0.22
Phenanthrene	<0.023	**0.038**	<0.023	<0.023	**0.092**	<0.072	**11,000**	**12**	<0.067
Pyrene	<0.058	<0.056	<0.058	<0.057	<0.057	<0.06	**2,500**	**3.6**	<0.056
TPH - mg/kg									
C6 - C10 Hydrocarbons	<58	<56	<58	<57	<57	<60	**8,600**	**350**	<56
>C10 - C28 Hydrocarbons	<58	<56	<58	<57	**100**	**170**	**270,000**	**2,100**	<56
TPH C6 - C28 Hydrocarbons	<58	<56	<58	<57	**160**	**170**	**280,000**	**2,400**	<56

Key at end of table.

Table 4-1 (cont.)

ORGANIC ANALYTICAL RESULTS IN SEDIMENT AND SOIL
WILCOX REFINERY, BRISTOW, OKLAHOMA

Sample Location Depth (ft)	SB17D 1-2	SB17 5.5-6.5	SB18 1-2	SB18 7-8	SB19 1-2	SB19 7-8	SB20 0-3	SB21 0-3	SB22 0-3
Analyte									
Volatiles (BTEX) - mg/kg									
Benzene	<0.0022	**0.13**	<0.086	**0.36**	<0.0022	<0.0023	<0.0054 JL	<0.0051	<0.0053
Ethylbenzene	<0.0022	**4.0**	**1.4**	**7.9**	**0.017 JH**	<0.0023	<0.0054 JL	<0.0051	<0.0053
Toluene	<0.0022	**2.8**	**0.24**	**0.39**	**0.0093 JH**	<0.0023	<0.0054 JL	<0.0051	<0.0053
Xylene (total)	<0.0022	**15**	**0.89**	**8.9**	**0.061 JH**	<0.0023	<0.0054 JL	<0.0051	<0.0053
Semi-Volatiles (PAHs) - mg/kg									
Acenaphthene	<0.22	**0.78**	<0.23	<4.7	<22	<0.23	<0.36	<0.34	<0.35
Acenaphthylene	<0.22	<0.23	<0.23	<4.7	<22	<0.23	<0.36	<0.34	<0.35
Anthracene	<0.022	<0.023	<0.023	**0.54**	<2.2	<0.023	<0.36	<0.34	<0.35
Benzo(a)anthracene	<0.022	**0.049**	**0.033**	**0.45 JK**	**2.8**	**0.012 JK**	<0.36	<0.34	<0.35
Benzo(b)fluoranthene	<0.022	<0.023	**0.0066 JK**	<0.47	**0.73 JK**	<0.023	<0.36	<0.34	<0.35
Benzo(k)fluoranthene	<0.022	<0.023	<0.023	<0.47	<2.2	<0.023	<0.36	<0.34	<0.35
Benzo(a)pyrene	<0.022	<0.023	**0.026**	<0.47	**1.2 JK**	<0.023	<0.36	<0.34	<0.35
Benzo(ghi)perylene	<0.056	<0.057	<0.057	<1.2	<5.6	<0.057	<0.36	<0.34	<0.35
Chrysene	<0.022	<0.023	<0.023	<0.47	<2.2	<0.023	<0.36	<0.34	<0.35
Dibenzo(a,h)anthracene	<0.056	<0.057	<0.057	<1.2	<5.6	<0.057	<0.36	<0.34	<0.35
Fluoranthene	<0.056	**0.11**	**0.28**	**5.4**	<5.6	<0.057	<0.36	<0.34	<0.35
Fluorene	<0.022	**0.048**	**0.044**	**1.4**	<2.2	<0.023	<0.36	<0.34	<0.35
Indeno(1,2,3-cd)pyrene	<0.022	<0.023	<0.023	<0.47	<2.2	<0.023	<0.36	<0.34	<0.35
1-Methylnaphthalene	<0.22	**0.52**	<0.23	**13**	<22	<0.23	NA	NA	NA
2-Methylnaphthalene	<0.22	**0.69**	**0.41**	**16**	<22	<0.23	NA	NA	NA
Naphthalene	<0.22	**0.59**	<0.23	<4.7	<22	<0.23	<0.36 JK	<0.34 JK	<0.35 JK
Phenanthrene	<0.067	**0.074**	**0.18**	**4.4**	<6.7	<0.068	<0.36	<0.34	<0.35
Pyrene	<0.056	<0.057	**0.13**	**2.2**	<5.6	<0.057	<0.36	<0.34	<0.35
TPH - mg/kg									
C6 - C10 Hydrocarbons	<56	**750**	<57	**550**	**200**	<57	<54.3	<51.1	<52.8
>C10 - C28 Hydrocarbons	<56	**310**	<57	**440**	**3,400**	<57	[redacted]702	<51.1	<52.8
TPH C6 - C28 Hydrocarbons	<56	[redacted]1,100 J	<57	[redacted]990	[redacted]3,700	<57	NR	NR	NR

Key at end of table.

Table 4-1 (cont.)

ORGANIC ANALYTICAL RESULTS IN SEDIMENT AND SOIL
WILCOX REFINERY, BRISTOW, OKLAHOMA

Sample Location Depth (ft)	SB23 0-3	SB24 0-2	SB25 0-3	SB26 0-2	SB27 0-3	SB28 0-2	SB29 0-1	SB30 0-3	SB31 0-3
Analyte									
Volatiles (BTEX) - mg/kg									
Benzene	<0.0051 JL	<0.0058 JL	<0.0051 JL	<0.0051 JL	<0.0052	<0.0052 JL	<0.0051	<0.0056	<0.0059
Ethylbenzene	<0.0051 JL	<0.0058 JL	<0.0051 JL	<0.0051 JL	<0.0052	<0.0052 JL	<0.0051	<0.0056	<0.0059
Toluene	<0.0051 JL	<0.0058 JL	<0.0051 JL	<0.0051 JL	<0.0052	<0.0052 JL	<0.0051	<0.0056	<0.0059
Xylene (total)	<0.0051 JL	<0.0058 JL	<0.0051 JL	<0.0051 JL	<0.0052	<0.0052 JL	<0.0051	<0.0056	<0.0059
Semi-Volatiles (PAHs) - mg/kg									
Acenaphthene	<0.34	<0.39	<0.34	<0.34	<3.5 JK	<3.5 JK	<3.4 JK	<3.7 JK	<4.0 JK
Acenaphthylene	<0.34	<0.39	<0.34	<0.34	<3.5 JK	<3.5 JK	<3.4 JK	<3.7 JK	<4.0 JK
Anthracene	<0.34	<0.39	<0.34	<0.34	<3.5	**4.9**	<3.4	<3.7	<4.0
Benzo(a)anthracene	**0.38**	**0.61**	**0.61**	**0.30**	<3.5 JL	<3.5 JL	<3.4 JL	<3.7 JL	<4.0 JL
Benzo(b)fluoranthene	**0.26**	<0.39	**0.52**	**0.26**	**0.50 JH**	**1.5 JH**	**0.40 JH**	<3.7 JK	<4.0 JK
Benzo(k)fluoranthene	<0.34	<0.39	<0.34	<0.34	<3.5	<3.5 JK	**0.48 JH**	<3.7 JK	<4.0 JK
Benzo(a)pyrene	**0.34**	<0.39	**0.41**	**0.23**	**0.57 JH**	**2.9 JH**	**0.75 JH**	<3.7JK	<4.0 JK
Benzo(ghi)perylene	**0.57**	<0.39	**0.27**	**0.30**	**0.54 JH**	**1.1 JH**	<3.4 JK	<3.7 JK	<4.0 JK
Chrysene	**0.85 JH**	<0.39	**0.81 JH**	**0.65 JH**	**1.7 JH**	**5.4**	**1.2**	<3.7	**0.77**
Dibenzo(a,h)anthracene	<0.34	<0.39	<0.34	<0.34	<3.5 JK	**0.53 JH**	<3.4	<3.7 JK	<4.0 JK
Fluoranthene	<0.34	<0.39	**0.85 JH**	<0.34	**0.40 JH**	**1.5**	**0.34**	<3.7	<4.0
Fluorene	<0.34	<0.39	<0.34	<0.34	<3.5 JK	<3.5 JK	<3.4	<3.7 JK	<4.0 JK
Indeno(1,2,3-cd)pyrene	<0.34	<0.39	**0.21**	<0.34	<3.5 JK	**0.51 JH**	**0.36 JH**	<3.7 JK	<4.0 JK
1-Methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	**0.18 JH**	<0.39	<0.34 JK	<0.34 JK	<3.5 JK	**0.37 JH**	<3.4	<3.7 JK	<4.0 JK
Phenanthrene	**1.5**	**0.76**	**1.3**	**1.1**	**1.7 JH**	**4.8**	**1.5**	<3.7	**0.70**
Pyrene	**1.2**	**1.5**	**1.2**	**0.72**	**1.9 JH**	**6.6**	**1.3**	<3.7	**0.70**
TPH - mg/kg									
C6 - C10 Hydrocarbons	<51.1	<58.4	<50.9	<51.4	<52.6	<52.3	<51.2	<56.1	<59.4
>C10 - C28 Hydrocarbons	<51.1	1,140	<50.9	<51.4	<52.6	<52.3	<51.2	<56.1	<59.4
TPH C6 - C28 Hydrocarbons	NR	NR	NR	NR	NR	NR	NR	NR	NR

Key at end of table.

Table 4-1 (cont.)

ORGANIC ANALYTICAL RESULTS IN SEDIMENT AND SOIL
WILCOX REFINERY, BRISTOW, OKLAHOMA

Sample Location Depth (ft)	SB32 0-1	SB32D 0-1	SB33 0-1	SB34 0-1	SB35 0-3	SB36 6-7	SB37 6-7	SB38 0-1	SB39 3-4
Analyte									
Volatiles (BTEX) - mg/kg									
Benzene	<0.0087	<0.0086	<0.0064	<0.0064	<0.0057	<0.0051 JL	<0.0054 JL	<0.0060 JL	<0.0060
Ethylbenzene	<0.0087	<0.0086	<0.0064	**0.14**	<0.0057	<0.0051 JL	<0.0054 JL	<0.0060 JL	<0.0060
Toluene	<0.0087	<0.0086	<0.0064	<0.0064	<0.0057	<0.0051 JL	<0.0054 JL	<0.0060 JL	<0.0060
Xylene (total)	<0.0087	<0.0086	**0.082**	<0.0064	<0.0057	<0.0051 JL	<0.0054 JL	<0.0060 JL	<0.0060
Semi-Volatiles (PAHs) - mg/kg									
Acenaphthene	<0.58	<0.58	<0.43	**2.3**	<0.38	<0.37	<0.36	<0.40	<0.39
Acenaphthylene	<0.58	<0.58	<0.43	<4.0	<0.38	<0.37	<0.36	<0.40	<0.39
Anthracene	<0.58	<0.58	<0.43	**19**	<0.38	<0.37	<0.36	<0.40	<0.39
Benzo(a)anthracene	<0.58 JL	<0.58 JL	**0.35 JL**	<4.0 JL	<0.38 JL	<0.37	<0.36	<0.40	<0.39 JL
Benzo(b)fluoranthene	<0.58	<0.58	**0.29**	**27 JH**	<0.38 JK	<0.37	<0.36	<0.40	<0.39
Benzo(k)fluoranthene	<0.58	<0.58	<0.43	<4.0 JK	<0.38 JK	<0.37	<0.36	<0.40	<0.39
Benzo(a)pyrene	<0.58	<0.58	<0.43	**14 JH**	<0.38	<0.37	<0.36	<0.40	<0.39
Benzo(ghi)perylene	<0.58	<0.58	**0.24**	**12 JH**	<0.38 JK	<0.37	<0.36	<0.40	<0.39
Chrysene	<0.58	<0.58	**1.0**	**20 JH**	<0.38 JK	<0.37	<0.36	<0.40	<0.39
Dibenzo(a,h)anthracene	<0.58	<0.58	<0.43	**5.4 JH**	<0.38 JK	<0.37	<0.36	<0.40	<0.39
Fluoranthene	<0.58	<0.58	<0.43	**34**	<0.38	<0.37	<0.36	<0.40	<0.39
Fluorene	<0.58	<0.58	<0.43	**24**	<0.38	<0.37	<0.36	<0.40	<0.39
Indeno(1,2,3-cd)pyrene	<0.58	<0.58	<0.43	**11 JH**	<0.38 JK	<0.37	<0.36	<0.40	<0.39
1-Methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	<0.58	<0.58	<0.43	**2.4 JH**	<0.38	<0.37 JK	<0.36 JK	<0.40 JK	<0.39 JK
Phenanthrene	<0.58	**0.31**	**0.97**	**220 JK**	<0.38	<0.37	<0.36	<0.40	<0.39
Pyrene	<0.58	**0.29**	**1.1**	**240 JH**	**0.36 JH**	<0.37	<0.36	<0.40	<0.39
TPH - mg/kg									
C6 - C10 Hydrocarbons	<87.3	<86.3	<64.3	<64.6	<57.1	<51.3	<53.6	<59.7	<60.0
>C10 - C28 Hydrocarbons	<87.3	<86.3	**125**	**270**	<57.1	<51.3	<53.6	<59.7	<60.0
TPH C6 - C28 Hydrocarbons	NR	NR	NR	NR	NR	NR	NR	NR	NR

Key at end of table.

Table 4-1 (cont.)

ORGANIC ANALYTICAL RESULTS IN SEDIMENT AND SOIL
WILCOX REFINERY, BRISTOW, OKLAHOMA

Sample Location Depth (ft)	SB40 3-4	SB41 2-3	SB41D 2-3	SB42 2-3	SB43 6-7	SB44 4-5	SB45 0-1	SB46 6-12	SB46D 6-12
Analyte									
Volatiles (BTEX) - mg/kg									
Benzene	<0.0059	<0.0061	<0.0056	<0.0059	<0.0054	<0.0056	<0.0063	<0.0059	<0.0057
Ethylbenzene	<0.0059	<0.0061	<0.0056	<0.0059	<0.0054	<0.0056	<0.0063	<0.0059	<0.0057
Toluene	<0.0059	<0.0061	<0.0056	<0.0059	<0.0054	<0.0056	<0.0063	<0.0059	<0.0057
Xylene (total)	<0.0059	<0.0061	<0.0056	<0.0059	<0.0054	<0.0056	<0.0063	<0.0059	<0.0057
Semi-Volatiles (PAHs) - mg/kg									
Acenaphthene	<0.39 JK	<0.41	<0.37	<0.39	<0.36	<0.37	<0.42	<0.39 JK	<0.38 JK
Acenaphthylene	<0.39 JK	<0.41	<0.37	<0.39	<0.36	<0.37	<0.42	<0.39 JK	<0.38 JK
Anthracene	<0.39	<0.41	<0.37	<0.39	<0.36	<0.37	<0.42	<0.39	<0.38
Benzo(a)anthracene	<0.39 JL	<0.41 JL	<0.37 JL	<0.39 JL	<0.36 JL	<0.37 JL	<0.42 JL	<0.39 JL	<0.38 JL
Benzo(b)fluoranthene	<0.39	<0.41	<0.37	<0.39	<0.36	<0.37	<0.42	<0.39	<0.38
Benzo(k)fluoranthene	<0.39	<0.41	<0.37	<0.39	<0.36	<0.37	<0.42	<0.39	<0.38
Benzo(a)pyrene	<0.39	<0.41	<0.37	<0.39	<0.36	<0.37	<0.42	<0.39	<0.38
Benzo(ghi)perylene	<0.39	<0.41	<0.37	<0.39	<0.36	<0.37	<0.42	<0.39	<0.38
Chrysene	<0.39	<0.41	<0.37	<0.39	<0.36	<0.37	<0.42	<0.39	<0.38
Dibenzo(a,h)anthracene	<0.39	<0.41	<0.37	<0.39	<0.36	<0.37	<0.42	<0.39	<0.38
Fluoranthene	<0.39	<0.41	<0.37	<0.39	<0.36	<0.37	<0.42	<0.39	<0.38
Fluorene	<0.39 JK	<0.41	<0.37	<0.39	<0.36	<0.37	<0.42	<0.39 JK	<0.38 JK
Indeno(1,2,3-cd)pyrene	<0.39	<0.41	<0.37	<0.39	<0.36 JK	<0.37	<0.42	<0.39	<0.38
1-Methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	<0.39 JK	<0.41 JK	<0.37 JK	<0.39 JK	<0.36	<0.37 JK	<0.42	<0.39 JK	<0.38 JK
Phenanthrene	**0.49 JH**	<0.41	<0.37	<0.39	<0.36	<0.37	<0.42	<0.39	<0.38
Pyrene	**0.20 JH**	<0.41	<0.37	<0.39	<0.36	<0.37	<0.42	<0.39	<0.38
TPH - mg/kg									
C6 - C10 Hydrocarbons	<58.9	<60.7	<55.7	<58.7	<54.2	<55.1	<62.8	<58.8	<56.8
>C10 - C28 Hydrocarbons	<58.9	<60.7	<55.7	<58.7	<54.2	<55.1	<62.8	<58.8	<56.8
TPH C6 - C28 Hydrocarbons	NR	NR	NR	NR	NR	NR	NR	NR	NR

Key at end of table.

ORGANIC ANALYTICAL RESULTS IN SEDIMENT AND SOIL
WILCOX REFINERY, BRISTOW, OKLAHOMA

Key:

Analytical results are reported in milligrams per kilogram (mg/kg)
Results in **bold** exceed laboratory reporting limits
BTEX - Benzene, toluene, ethylbenzene, and xylenes
D - Duplicate sample
H - The bias in the estimated value is high
J - Concentration is estimated

Shaded results exceed one or more example regulatory criteria in Table 11

K - The bias in the estimated value is unknown
L - The bias in the estimated value is low
NA - Not analyzed
NR - Not reported
PAHs - Polycyclic aromatic hydrocarbons
SB - Soil boring sample

SED - Sediment sample
TPH - Total petroleum hydrocarbons
< - Not detected at the laboratory reporting limit
>C10-C28 - Number of carbon atoms in the range of totaled hydrocarbon concentrations

Table 4-2

INORGANIC ANALYTICAL RESULTS IN SEDIMENT AND SOIL
WILCOX REFINERY, BRISTOW, OKLAHOMA

Sample Location Depth (ft)	SED11 0-1	SED12 0-1	SB01 0-0.5	SB01 10-11	SB02 1-2	SB03 1.5-2	SB04 4-5	SB05 1-2	SB05 4-5	SB05 14-15	SB06 1-2	SB07 4-5	SB07D 4-5	SB08 1-2
Metals - mg/kg														
Aluminum	1,210 JL	960 JL	727 JL	3,620 JL	1,140	911	1,230	1,740	1,930	3,000	2,590	4,760	3,780	1,250
Antimony	<7.5 JK	<7.2 JK	<6.3 JK	<6.9 JK	<1.0	<1.0	<1.0	<1.1	<1.2	<1.2	<1.1	<1.2	<1.1	<1.1
Arsenic	1.4 JH	1.6 JH	1.0 JH	2.8 JH	0.99	0.68	0.97	2.4	1.1	4.0	2.1	4.1	3.4	1.8
Barium	20.2	22.1	19.1	72.7	10.2	7.5	7.3	23.8	51	89.8	28.8	31.9	26.9	20
Beryllium	<0.62	<0.60	<0.53	<0.57	<0.51	<0.52	<0.52	<0.56	<0.62	<0.58	<0.56	<0.58	<0.55	<0.53
Cadmium	<0.62 JK	<0.60 JK	5.1 JK	1.6 JK	<0.51	<0.52	<0.52	0.81	<0.62	1.9	0.75	1.2	1.2	0.53
Calcium	561 JK	373 JK	2,550 JK	888 JK	167 JH	160 JH	169 JH	363 JH	631JH	351 JH	380 JH	745 JH	531 JH	189 JH
Chromium	3.7	4.0	13.6	6.7	2.4	1.7	2.1	5.3	5.4	12.2	5.8 JK	13.2 JK	11.6 JK	3.6 JK
Cobalt	<2.5	<2.4	2.8	5.6	2.4	<2.1	<2.1	2.3	3.6	7.7	<2.3	2.7	2.6	<2.1
Copper	2.7 JK	2.7 JK	78.1 JK	6.3 JK	<2.0	<2.1	<2.1	<2.3	<2.5	<2.3	<2.3	3.3	3.7	<2.1
Iron	3,520 JK	4,050 JK	37,300 JK	13,000 JK	2,790	1,840	2,470	5,290	3,500	13,400	5,130	8,400	7,870	3,430
Lead	32.4 JK	16.7 JK	4,980 DJK	6.5 JK	1.1	0.83	1.1	7.0	3.7	4.9	3.0 JK	6.1 JK	17.9 JK	10.5 JK
Magnesium	311 JK	226 JK	246 JK	565 JK	52.8	<52.0	77.9	185	305	285	210	378	289	110
Manganese	104 JK	142 JK	182 JK	426 JK	164 JK	49.9 JK	12.8 JK	207 JK	26.8 JK	231 JK	112 JK	47.5 JK	87.1 JK	134 JK
Mercury	<0.02	<0.02	0.06	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.04	0.06	0.07	0.06
Nickel	2.6 JK	<2.4	4.0 JH	14.5 JH	<2.0	<2.1	<2.1	<2.3	3.9	5.4	<2.3	2.7	<2.2	<2.1
Potassium	253	221	126	386	425	648	507	400	408	609	412	601	529	264
Selenium	<0.62	<0.60	1.1	0.65 JH	<1.0	<1.0	<1.0	<0.56	<1.2	<1.2	<1.1	<1.2	<1.1	<1.1
Silver	<1.2 JL	<1.2 JL	<1.1 JL	<1.1 JL	<1.0	<1.0	<1.0	<1.1	<1.2	<1.2	<1.1	<1.2	<1.1	<1.1
Sodium	<62.1	68.6 JH	268 JH	2,620 JH	121	<110	219	<110	143	81.2	<114	123	164	<108
Thallium	<0.62	<0.60	<0.53	<0.57	<0.51	<0.52	<0.52	<0.56	<0.62	<0.58	<0.56	<0.58	<0.55	<0.53
Vanadium	5.4	7.5	<2.1	11	3.9	3.1	4.0	7.6	9.7	13.8	9.2	14.4	13.2	5.9
Zinc	9.8 JK	5.3 JK	43.3 JK	7.4 JK	3.4	1.7	1.6	11.8	6.4	12.6	5.0 JK	7.6 JK	10.2 JK	5.0 JK
pH	7.1	7.1	8	8.8	6.1	5.5	6.6	6.7	6.4	6.6	3.2	3.1	3.3	2.3

Key:

Metals reported in milligrams per kilogram (mg/kg)
Results in bold exceed laboratory reporting limits
Shaded results exceed 20 times RCRA TCLP criteria in Table 5-2
pH results in bold are <5 or >9
pH reported in standard pH units
B - Analyte detected in associated blank
D - Duplicate sample
H - The bias in the estimated value is high
J - Concentration is estimated
K - The bias in the estimated value is unknown
L - The bias in the estimated value is low
NA - Not analyzed
NR - Not reported
SB - Soil boring sample
SED - Sediment sample
< - Not detected at the laboratory reporting limit

Table 4-2 (cont.)

INORGANIC ANALYTICAL RESULTS IN SEDIMENT AND SOIL
WILCOX REFINERY, BRISTOW, OKLAHOMA

Sample Location Depth (ft)	SB09 1-2	SB10 3-4	SB11 2-3	SB12 1-2	SB12 8-9	SB13 1-2	SB13 6.5-7.5	SB13D 6.5-7.5	SB14 1-2	SB14 5-6	SB15 0-1	SB16 5-6	SB17 1-2
Metals - mg/kg													
Aluminum	3,540	2,110	3,600	4,480	1,600	3,600	3,160	2,290	1,700	9,190	24.8	3,370	9,700
Antimony	<1.1	<1.1	<1.2	<1.1	<1.1	<1.1	<1.1	<1.2	<1.1	1.4	<1.2	<1.2	<1.1
Arsenic	2.8	1.3	2.3	3.0	0.88	4.5	3.9	2.4	0.95	5.4	<0.62	1.9	2.7
Barium	27.4	15.1	54.8	77	16.5	23.2	45.4	39.3	23.5	107	<2.5	21.3	60.5
Beryllium	<0.56	<0.53	<0.59	<0.56	<0.56	<0.54	<0.57	<0.58	<0.55	0.81	<0.62	<0.58	<0.54
Cadmium	1.1	0.59	0.99	1.4	<0.56	1.4	1.8	1.1	0.58	2.8	<0.62	0.82	1.5
Calcium	646 JH	522 JH	798 JH	818 JH	512 JH	585 JH	1,010 JH	786 JH	264	445	87.3	334	1,470
Chromium	8.3 JK	6.5 JK	8.4 JK	8.6 JK	4.0 JK	7.8 JK	10.3 JK	7.5 JK	4.3	15.2	<1.2	6.8	11.2
Cobalt	<2.2	<2.1	2.8	4.1	<2.3	2.6	4.3	3.6	2.3	9.8	<2.5	2.3	2.9
Copper	<2.2	2.2	6.4	4.5	<2.3	2.9	4.7	3.2	<2.2	12.7	<2.5	3.9	6.1
Iron	7,820	4,270	6,770	9,530	1,870	9,930	12,700	8,040	3,810	18,100	262	5,490	10,100
Lead	5.0 JK	2.0 JK	20.9 JK	4.7 JK	1.7 JK	48 JK	5.5 JK	3.5 JK	114	7.4	2.5	2.6	10.3
Magnesium	318	431	582	634	337	414	763	615	241	1,510	<61.5	279	728
Manganese	103 JK	43.4 JK	59.9 JK	156 JK	24.0 JK	25.3 JK	76.7 JK	52.0 JK	86.2	103	3.0	44.2	56
Mercury	0.05	0.04	0.03	0.05	0.05	0.04	0.05	0.05	0.04	0.04	<0.02	0.04	0.04
Nickel	3.2	2.2	3.3	5.6	<2.3	3.2	8.1	6.8	3.1	13.1	<2.5	3.5	5.5
Potassium	466	340	487	562	299	568	506	500	412	1,040	<123	546	1,110
Selenium	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.2	<1.1	<1.2	<1.2	<1.2	<1.1
Silver	<1.1	<1.1	<1.2	<1.1	<1.1	<1.1	<1.1	<1.2	<1.1	<1.2	<1.2	<1.2	<1.1
Sodium	<111	232	<117	254	156	<112	<116	115	1,620 JK	4,690 JK	<123 JK	<115 JK	<108 JK
Thallium	<0.56	<0.53	<0.59	<0.56	<0.56	<0.54	<0.57	<0.58	<0.55	<0.60	<0.62	<0.58	0.54
Vanadium	12.6	7.0	12.8	14.5	3.5	13.7	21.4	12.1	5.1	27.7	<2.5	10.4	20
Zinc	5.6 JK	4.7 JK	13.3 JK	8.4 JK	4.0 JK	9.2 JK	10.5 JK	8.7 JK	5.8	18.7	<1.2	4.8	15.2
pH	3.0	2.8	4.7	3.8	5.9	3.9	6.0	5.9	9.5	9.4	8.1	6.6	7.4

Key:

Metals reported in milligrams per kilogram (mg/kg)
Results in bold exceed laboratory reporting limits
Shaded results exceed 20 times RCRA TCLP criteria i
pH results in bold are <5 or >9
pH reported in standard pH units
B - Analyte detected in associated blank
D - Duplicate sample
H - The bias in the estimated value is high
J - Concentration is estimated
K - The bias in the estimated value is unknown
L - The bias in the estimated value is low
NA - Not analyzed
NR - Not reported
SB - Soil boring sample
SED - Sediment sample
< - Not detected at the laboratory reporting limit

Table 4-2 (cont.)

INORGANIC ANALYTICAL RESULTS IN SEDIMENT AND SOIL
WILCOX REFINERY, BRISTOW, OKLAHOMA

Sample Location Depth (ft)	SB17D 1-2	SB17 5.5-6.5	SB18 1-2	SB18 7-8	SB19 1-2	SB19 7-8	SB20 0-3	SB21 0-3	SB22 0-3	SB23 0-3	SB24 0-2	SB25 0-3	SB26 0-2
Metals - mg/kg													
Aluminum	7,840	4,110	2,510	5,300	1,570	4,110	1,770	1,260	4,290	1,350	1,140	1,280	3,010
Antimony	<1.1	<1.1	<1.1	<1.2	<1.1	<1.1	1.3 R	<0.50 R	1.00 R	<0.50 R	1.1 R	<0.50 R	<0.50 R
Arsenic	1.5	1.7	2.1	3.3	1.5	0.83	2.7 R	2.7 R	2.2 R	1.8 R	2.7 R	2.2 R	1.7 R
Barium	53.9	31.6	50.3	68.1	25.6	33.6	37.7	15.5	58.8	20.9	31.4	16.0	24.8
Beryllium	<0.54	<0.55	<0.56	<0.58	<0.53	<0.57	0.12 R	0.08 R	0.25 R	0.12 R	0.13 R	0.10 R	0.17 R
Cadmium	0.98	1.2	0.79	1.6	0.63	<0.57	0.14 R	0.07 R	0.10 R	0.17 R	0.25 R	0.44 R	0.11 R
Calcium	1,420	342	924	678	1,480	754	594	18,400	471	619	4,190	10,700	898
Chromium	10.5	6.8	6.8	9.4	5.8	8.6	6.1 JK	4.1 JK	6.2 JK	3.5 JK	5.2 JK	4.9 JK	5.4 JK
Cobalt	2.4	2.8	2.6	5.3	2.3	<2.3	1.0 R	1.0 R	3.2 R	1.4 R	2.3 R	1.3 R	1.8 R
Copper	4.9	5.3	6.3	6.1	3.5	3.5	15.7	3.6	7.9	8.4	122	12.9	4.9
Iron	6,400	7,910	5,010	10,300	3,750	2,930	4,800 JK	4,000 JK	5,120 JK	4,960JK	7,840 JK	6,140 JK	4,100 JK
Lead	6	3.7	24.8	10.7	14.7	1.9	1,960 JK	61.6 JK	4.2 JK	181 JK	724 JK	125 JK	72.2 JK
Magnesium	628	478	351	606	550	785	327	9,910	490	300	2,140	5,890	595
Manganese	37.5	130	128	111	138	34.5	27.1	424	165	127	223	208	99
Mercury	0.03	0.04	0.11	0.05	0.11	0.05	0.39	NR	<0.11	0.13	<0.12	<0.10	<0.10
Nickel	5.0	4.1	3.6	6.3	4.4	2.8	3.9	2.7	4.9	3.3	6.4	4.5	4.4
Potassium	932	552	388	504	286	500	356	475	679	339	256	342	595
Selenium	<1.1	<1.1	<1.1	<1.2	<1.1	<1.1	<0.49	<0.46	0.48	<0.46	<0.53	<0.46	<0.46
Silver	<1.1	<1.1	<1.1	<1.2	<1.1	<1.1	<1.2 B	<1.4 B	<0.99 B	<1.1 B	<1.3 B	<1.5 B	<1.0 B
Sodium	<108 JK	<109 JK	<113 JK	<115 JK	<106 JK	174 JK	67.8	97	57	70	154	192	119
Thallium	<0.54	<0.55	<0.56	<0.58	<0.53	<0.57	<0.27	<0.26	<0.26	<0.26	<0.29	<0.25	<0.26
Vanadium	17.4	10	10.1	16.2	6.6	3.8	6.6 JK	4.9 JK	9.2 JK	5.0 JK	5.7 JK	4.8 JK	6.8 JK
Zinc	10.2	8.4	16	8.2	25.6	3.1	15.4 JK	14.1 JK	6.2 JK	18.3 JK	61.9 JK	83.8 JK	14.3 JK
pH	7.3	5.6	7.7	6.1	7.4	6.3	5.9	7.7	6.2	6.2	7.1	6.9	7.2

Key:

Metals reported in milligrams per kilogram (mg/kg)
Results in bold exceed laboratory reporting limits
Shaded results exceed 20 times RCRA TCLP criteria i
pH results in bold are <5 or >9
pH reported in standard pH units
B - Analyte detected in associated blank
D - Duplicate sample
H - The bias in the estimated value is high
J - Concentration is estimated
K - The bias in the estimated value is unknown
L - The bias in the estimated value is low
NA - Not analyzed
NR - Not reported
SB - Soil boring sample
SED - Sediment sample
< - Not detected at the laboratory reporting limit

Table 4-2 (cont.)

INORGANIC ANALYTICAL RESULTS IN SEDIMENT AND SOIL
WILCOX REFINERY, BRISTOW, OKLAHOMA

Sample Location Depth (ft)	SB27 0-3	SB28 0-2	SB29 0-1	SB30 0-3	SB31 0-3	SB32 0-1	SB32D 0-1	SB33 0-1	SB34 0-1	SB35 0-3	SB36 6-7	SB37 6-7	SB38 0-1
Metals - mg/kg													
Aluminum	3220 JK	2,240 JK	1,460 JK	2,350 JK	2,190 JK	2,090 JK	1,870 JK	11,300 JK	3,410 JK	4,180 JK	1,290	915	44.6
Antimony	<0.51 JL	0.76 JL	0.80 JL	<0.55 JL	<0.58 JL	<0.86 JL	<0.85 JL	<0.63 JL	<0.63 JL	<0.56 JL	<0.50 R	<0.53 R	<0.01 R
Arsenic	2.3	3.0	1.4	1.2	0.73	8.3	11.4	4.0	3.5	1.0	1.0 R	0.45 R	0.01 R
Barium	51.8	42.6	21.9	32.7	28.7	84.6	104	171	53.0	36.7	10.9	9.4	0.28
Beryllium	0.21	0.28	0.11	0.19	0.15	0.12	0.14	0.73	0.23	0.20	0.09 R	0.05 R	0 R
Cadmium	0.19	0.20	0.10	0.12	0.07	0.15	0.25	0.13	0.08	0.24	<0.05 R	<0.05 R	<0 R
Calcium	3,460	951	1,560	828	321	1,370	1,630	1,110	717	6,590	211	148	3.9
Chromium	6.1	15.0	3.5	4.6	3.8	3.9	3.6	14.1	6.7	4.5	3.3 JK	1.6 JK	0.06 JK
Cobalt	2.5	3.0	1.6	2.2	2.0	3.8	3.0	5.1	3.9	1.3	1.1 R	0.29 R	<0.01 B R
Copper	8.1	7.3	4.5	4.5	19.0	4.0	3.8	5.8	11.7	8.9	2	<1.5 B	<0.03 B
Iron	5,310	8,630	2,690	3,920	3,180	25,300	31,500	14,600	8,990	4,260	2,330 JK	769 JK	31.7 JK
Lead	141	450	162	77.2	811	194	245	15.3	1,080	15,200	<3.2 BJK	<2.8 BJK	<0.04 BJK
Magnesium	1,890	443	796	401	271	392	421	1,580	628	2,120	201	151	6.7
Manganese	176 JL	213 JL	157 JL	338 JL	78.7 JL	921 JL	1,100 JL	179 JL	301 JL	87.4 JL	50.9	4.1	0.23
Mercury	<0.11	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.11	<0.12
Nickel	4.9	3.9	2.4	2.8	3.2	0.94	0.52	10.7	5.1	3.1	18.3	1.9	<0.05 B
Potassium	704 JK	243 JK	168 JK	472 JK	588 JK	691 JK	218 JK	1,820 JK	764 JK	495 JK	350	360	9.1
Selenium	<0.47	<0.47	<0.46	<0.51	<0.53	<0.79	<0.78	<0.58	<0.58	<0.51	<0.46	<0.48	<0.01
Silver	0.59	<0.13	<0.12	0.20	0.35	2.3	2.0	<0.15	0.88	0.27	1.0	<1.7 B	<0.01 B
Sodium	142	90	71	86.6	98.5	202	112	190	159	143	53.2	55.6	<0.65 B
Thallium	<0.26	<0.26	<0.26	<0.28	<0.30	<0.44	<0.43	<0.32	<0.32	<0.29	<0.26	<0.27	NR
Vanadium	9.1	9.2	4.2	7.2	6.6	6.1	8.7	23.9	10.1	6.1	4.2	2.6 JK	<0.11 B JK
Zinc	29.6	29.6	13.7	22.3	12.2	7.7	8.0	19.4	14.7	7.6	4	0.75 JK	0.06 JK
pH	7.1	6.1	6.3	6.2	6.3	5.4	6.7	5.3	5.2	5.1	6.4	6.4	6.5

Key:

Metals reported in milligrams per kilogram (mg/kg)
Results in bold exceed laboratory reporting limits
Shaded results exceed 20 times RCRA TCLP criteria i
pH results in bold are <5 or >9
pH reported in standard pH units
B - Analyte detected in associated blank
D - Duplicate sample
H - The bias in the estimated value is high
J - Concentration is estimated
K - The bias in the estimated value is unknown
L - The bias in the estimated value is low
NA - Not analyzed
NR - Not reported
SB - Soil boring sample
SED - Sediment sample
< - Not detected at the laboratory reporting limit

Table 4-2 (cont.)

INORGANIC ANALYTICAL RESULTS IN SEDIMENT AND SOIL
WILCOX REFINERY, BRISTOW, OKLAHOMA

Sample Location Depth (ft)	SB39 3-4	SB40 3-4	SB41 2-3	SB41D 2-3	SB42 2-3	SB43 6-7	SB44 4-5	SB45 0-1	SB46 6-12	SB46D 6-12
Metals - mg/kg										
Aluminum	**4,570 JK**	**3,020 JK**	**2,760 JK**	**1,800 JK**	**2,280 JK**	**2,410 JK**	**1,420 JK**	**2,660 JK**	**5,640 JK**	**26.4 JK**
Antimony	<0.59 JL	<0.58 JL	<0.60 JL	<0.55 JL	<0.58 JL	<0.53 JL	<0.54 JL	<0.62 JL	<0.58 JL	<0.01 JL
Arsenic	**3**	**5.7**	**1.5**	**1.1**	**4.2**	**1.6**	**0.73**	**2.2**	**3**	**0.01**
Barium	**27.2**	**48.4**	**33.1**	**15.5**	**22.6**	**28.0**	**14.3**	**27.1**	**43.7**	**0.42**
Beryllium	**0.36**	**0.29**	**0.24**	**0.12**	**0.25**	**0.21**	**0.11**	**0.19**	**0.39**	NR
Cadmium	<0.06	**0.06**	<0.06	<0.06	<0.06	**0.07**	<0.06	<0.06	**0.06**	NR
Calcium	**606**	**528**	**536**	**324**	**333**	**292**	**199**	**289**	**463**	**2.3**
Chromium	**8.4**	**5.6**	**4.6**	**3.7**	**6.4**	**5.4**	**3**	**4.5**	**7.6**	**0.04**
Cobalt	**3.2**	**3.2**	**2.7**	**1.3**	**2.4**	**2.1**	**0.95**	**2**	**3**	**0.02**
Copper	**3.1**	**2.2**	**3.3**	**2.1**	**2.7**	**2**	**4.1**	**3.8**	**5.7**	<0.03 B
Iron	**8,820**	**10,400**	**5,250**	**3,260**	**8,180**	**5,990**	**2,430**	**5,830**	**9,260**	**26.3**
Lead	**3.6**	**3.2**	**6.6**	**3.8**	**4.4**	**2.2**	<1.6 B	**38.9**	**142**	<1.8 B
Magnesium	**653**	**483**	**476**	**271**	**370**	**369**	**215**	**402**	**688**	**3.6**
Manganese	**60.9 JL**	**312 JL**	**40.0 JL**	**45.1 JL**	**114 JL**	**84.4 JL**	**32.4 JL**	**39.5 JL**	**95.7 JL**	**0.16 JL**
Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel	**6.9**	**4.3**	**5.6**	**3.2**	**3.9**	**12.5**	**7.8**	**4.5**	**9.1**	**0.05**
Potassium	**917 JK**	**514 JK**	**501 JK**	**569 JK**	**547 JK**	**387 JK**	**311 JK**	**700 JK**	**894 JK**	**5.9 JK**
Selenium	<0.54	<0.53	<0.55	<0.5	<0.53	<0.49	<0.5	<0.57	<0.53	<0.01
Silver	**0.19**	**0.47**	**0.35**	**0.71**	**0.91**	**0.13**	**0.5**	**0.82**	**0.67**	<0.01 B
Sodium	**63.3**	**60.9**	**76.1**	**105**	**129**	**41.1**	**61.7**	**123**	**573**	**4.3**
Thallium	<0.3	<0.29	<0.3	<0.28	<0.29	<0.27	<0.28	<0.31	<0.29	NR
Vanadium	**13.6**	**10.3**	**8.5**	**5.5**	**11.3**	**8.5**	**4**	**7.2**	**16.2**	**0.05**
Zinc	**6.2**	**4.2**	**5.8**	**4**	**4**	**4.1**	**3.4**	**8**	**6.7**	0.04 B
pH	5.7	5.3	4.9	4.6	4.8	5.2	5.1	4.4	6.2	6.0

Key:

Metals reported in milligrams per kilogram (mg/kg)
Results in bold exceed laboratory reporting limits
Shaded results exceed 20 times RCRA TCLP criteria i
pH results in bold are <5 or >9
pH reported in standard pH units
B - Analyte detected in associated blank
D - Duplicate sample
H - The bias in the estimated value is high
J - Concentration is estimated
K - The bias in the estimated value is unknown
L - The bias in the estimated value is low
NA - Not analyzed
NR - Not reported
SB - Soil boring sample
SED - Sediment sample
< - Not detected at the laboratory reporting limit

Table 4-3

ORGANIC ANALYTICAL RESULTS IN GROUND WATER
WILCOX REFINERY, BRISTOW, OKLAHOMA

Sample ID/Location	GW1(SB05)	GW2(SB13)	GW3(SB15)	GW3D(SB15)	GW4(SB17)	GW5(SB18)	GW6(SB40)	GW7(SB42)	GW8(SB37)
Analyte									
Volatiles (BTEX) - mg/L									
Benzene	<2.0	<0.05	**0.049 JL**	**0.012**	<0.05	[redacted]	<0.005	<0.005	<0.005
Toluene	<2.0	<0.05	**0.034 JL**	**0.0087**	<0.05	< 2.0	<0.005	<0.005	<0.005
Ethylbenzene	**0.19**	**0.21**	**0.011 JL**	**0.0083**	**0.49**	**3.3**	<0.005	<0.005	<0.005
Xylene (total)	**0.035**	<0.05	**0.064 JL**	**0.018**	**0.14**	**9.1**	<0.005	<0.005	<0.005
TPH - mg/L									
C6 - C10 Hydrocarbons	**100**	**140**	<5.0	<5.0	[redacted]	[redacted]	<5.0	<5.0	NA
>C10 - C28 Hydrocarbons	**20**	**530**	**10**	**13**	<100	**5,900**	<5.0	<5.0	NA
TPH C6 - C28 Hydrocarbons	[redacted]	[redacted]	**10**	**13**	[redacted]	[redacted]	NR	NR	NA

Key:

Analytical results are reported in milligrams per liter
Results in **bold** exceed laboratory reporting limits
Shaded results exceed one or more example regulatory criteria in Table 5-1
BTEX - Benzene, toluene, ethylbenzene, and xylenes
D - Duplicate sample
GW(SB) - Ground water sample number (Soil boring location)
J - Concentration is estimated
L - The bias in the estimated value is low
NA - Not analyzed
NR - Not reported
>C10 - C28 - Number of carbon atoms in the range of totaled hydrocarbons
< - Not detected at the laboratory reporting limit

Table 4-4

SUMMARY OF DATA COMPLETENESS
WILCOX REFINERY, BRISTOW, OKLAHOMA

Control Limits	Data Assessment	
Analyte >90%	**TPH in water**	**87.5%**
	Antimony	**82.5%**
	Arsenic	**82.5%**
	Beryllium	**81%**
	Cadmium	**81%**
	Cobalt	**82.5%**
	Mercury	98%
	Thallium	96.5%
Analytical Method >90%	BTEX	100%
	PAHs	100%
	TPH	98.5%
	Metals	96%

Key:

Completeness results in **bold** for individual analytes fail analytical method completeness goals.

BTEX - Benzene, toluene, ethylbenzene, and xylenes.
PAHs - Polycyclic aromatic hydrocarbons.
TPH - Total petroleum hydrocarbons.

Table 4-5

SOURCE INVENTORY AND PRELIMINARY ESTIMATES OF WASTE QUANTITY
WILCOX REFINERY, BRISTOW, OKLAHOMA

Source	Concern/Status	Level of Threat to Waters	Capacity/ Dimension	Source Area (ft^2)	Estimated Thickness of Contamination (ft or inches)	Estimated Waste Volume (yd^3)	COCs (ESI and EPA START)*
Pond 1	Oily sludge/backfilled	Low	250 ft x 100 ft 3 cells	25,000	3 ft of oily waste and soil (Avg. of SB02, 03, 04)	2,780	Pyrene, toluene, xylenes, TPH
Pond 2	Runoff sediment from pit area 1 cell breached, 1 cell ponded	High	225 ft x 150 ft 1 of 2 cells	33,750	12 ft of soil and sediment	15,000	Copper, lead, TPH
Oily Waste Pit	Oily sludge/ berm breached, backfilled	Medium	300 ft diameter	70,686	3 ft of oily waste and soil (Avg. of SB07, 08, 09)	7,854	Acetone, 2-methyl-naphthalene, phenanathrene, xylenes, arsenic, copper, TPH
(b) (6) Pond	Stained sediment/ stock watering pond	High	100 ft x 60 ft	6,000	3 ft of sediment	667	Chromium, copper, lead
Ten Former Tank Farm Large ASTs	Tank bottom sludge/tank steel salvaged prior to 1967	Medium to low	55,000 bbl ea. 125 ft dia. x 25 ft.	12,272 each	2 inches of semi-solid TBS	76 ea. 760 total	Pyrene, cyanide, manganese, selenium, silver, zinc, TPH
(b) (6) Residence Soil	Surface and subsurface soil/on-site residents	Low	200 ft x 175 ft lot (-25% for house and shed)	26,250	5 ft average depth to ground water (SB17)	4,860	Lead, mercury, zinc, benzo(g,h,i)perylene chrysene, phenanthrene, pyrene
Unvegetated Area (South end of (b) (6) Property)	Bare, stained surface soil, odor/unchanged	High	200 ft x 150 ft	30,000	5 ft average depth to ground water (SB14)	5,556	Copper, lead, acidity

Key at end of table.

Table 4-5 (Cont.)

SOURCE INVENTORY AND PRELIMINARY ESTIMATES OF WASTE QUANTITY
WILCOX REFINERY, BRISTOW, OKLAHOMA

Source	Concern/Status	Level of Threat to Waters	Capacity/ Dimension	Source Area (ft^2)	Estimated Thickness of Contamination (ft or inches)	Estimated Waste Volume (yd^3)	COCs (ESI or EPA START)*
(b) (6) Residence Former Ponds	Subsurface soil/backfilled, on-site residents	Medium	150 ft x 100 ft (house pond) 300 ft x 100 ft (South pond)	15,000 30,000	8 ft to ground water (SB13)	4,444 8,889 Total 13,333	Acetone, TPH
Former Pond (b) (6) Property at SB01)	Bare cinders at surface/oily subsurface soil	High	125 ft x 100 ft	12,500	10 ft average to rock (SB01)	4,630	BTEX, TPH, lead
Former Pumping Station Soil	Subsurface soil/ No surface sampling to date	Medium	250 ft x 200 ft (fenced area) [25% impacted]	12,500	8 ft average depth to ground water (SB18)	3,704	Benzene, TPH
Former Refinery Area Soil	Surface soil/ No sampling to date	Medium	Unknown	Unknown	Unknown	Unknown	Suspected BTEX, PAHs, metals, TPH
Large ASTs ((b) (6) Property)	Minor TBS, Stained soil/Existing ASTs	Low	3,400 bbl each 144,000 gal 35 ft dia. X 20 ft	1,000 (Soil) plus 962 (TBS)	8 ft to rock (SB19) plus 2 inches of TBS in 1 tank	300 plus 1,200 gal	TPH
Small AST (b) (6) Property)	Diesel/Fuel Oil/ Existing AST	Medium	560 bbl 23,500 gal 20 ft dia. X 10 ft	10,000 (Soil) plus 314 (TBS)	4 ft to ground water (SB16), 9 inches of TBS	1,480 plus 1,760 gal	TPH
Rail Tanker	Minor spills of fuel oil/active AST	Medium	20,000 gal	100	3 inches of stained soil	1	Fuel oil
South Central Tank Berm Area	Stained soil/ Backfilled former AST berm area	Medium	300 ft dia. (25% impacted)	17,670	15 ft to ground water (SB05)	9,817	TPH
(b) (6) Tank Berm Area	Oily near surface soil/berm breached, backfilled	Medium	300 ft dia. (25% impacted)	17,670	3 ft to rock (SB11)	1,963	Benzo(a)pyrene, TPH

Key at end of table.

Table 4-5 (Cont.)

SOURCE INVENTORY AND PRELIMINARY ESTIMATES OF WASTE QUANTITY
WILCOX REFINERY, BRISTOW, OKLAHOMA

Source	Concern/Status	Level of Threat to Waters	Capacity/ Dimension	Source Area (ft^2)	Estimated Thickness of Contamination (ft or inches)	Estimated Waste Volume (yd^3)	COCs (ESI or EPA START)*
Former o/w Separator (b) (6) Property)	Oily soil, tarry waste/separator breached	High	33 ft x 15 ft (Soil) 30 ft x 10 ft (Tar)	500 300	1 ft to ground water (SB15) 6 inches average of tar	18.5 5.5 Total 24	Benzo(a)pyrene, PAHs, TPH
Upper reaches of Tributary 1	Stream bed soil/sed	High	800 ft of impacted stream bed	2,400	1 ft soil/sed (SB20 to SB29)	89	Lead, TPH
Lower reaches of Tributary 1	Oily liquid flowing into stream	High	250 ft of impacted stream bed	Unknown (pipe from (b) (6) property)	2 ft soil/sed (SB33, 34)	167 soil/sed plus unknown gal/min	PAHs, lead, TPH
					Total	72,985 yd^3 plus >2,960 gal	Solid Waste Liquid Waste

Key:

*Expanded Site Inspection (ESI) report (Roy F. Weston, March 1997) and the U.S. Environmental Protection Agency Superfund Technical Assistance and Response Team (START) site sampling events (Ecology and Environment, Inc., April, June, August, 1998).

AST - Aboveground storage tank
bbl - Barrel
BTEX - Benzene, toluene, ethylbenzene, and xylenes
COCs - Contaminants of concern
dia. - Diameter
ft - Feet
ft^2 - Square feet
gal - Gallons
> - Greater than
min - Minute
O/W - Oil/water
PAHs - Polycyclic aromatic hydrocarbons
sed - Sediment
SB - Soil boring sample
TBS - Tank bottom sludge
TPH - Total petroleum hydrocarbons
yd^3 - Cubic yard

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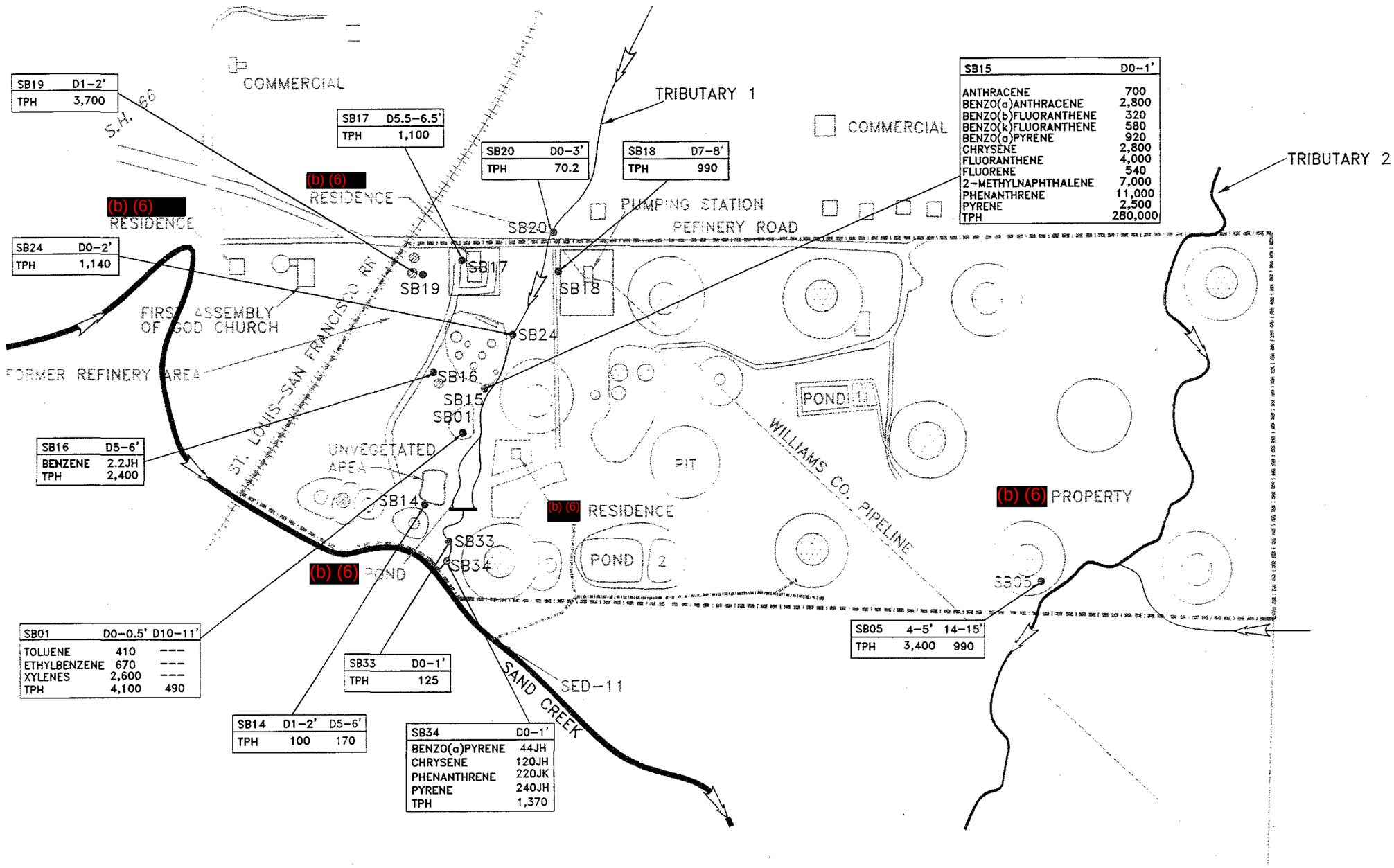

NOTES	LEGEND
ALL CONCENTRATIONS ARE LISTED IN MILLIGRAMS PER KILOGRAM (mg/kg). FOR A SUMMARY OF ORGANIC ANALYTICAL RESULTS, SEE TABLE 4-1 --- NOT DETECTED, OR NOT PRESENT IN SIGNIFICANT CONCENTRATIONS. D5.5-6.5' - DEPTH OF SAMPLE COLLECTION IN FEET BELOW GRADE.	FORMER TANK LOCATION OUTLINE OF BERM SEEP BUILDING EXISTING TANKS SITE BOUNDARY POND DRAINAGE DITCH SEDIMENT SAMPLE LOCATION SOIL BORING LOCATION DIRECTION OF FLOW

BASE MAP SOURCE: ROY F. WESTON INC., ESI REPORT, MARCH, 1997, FROM ACE AERIAL PHOTO, 1966.

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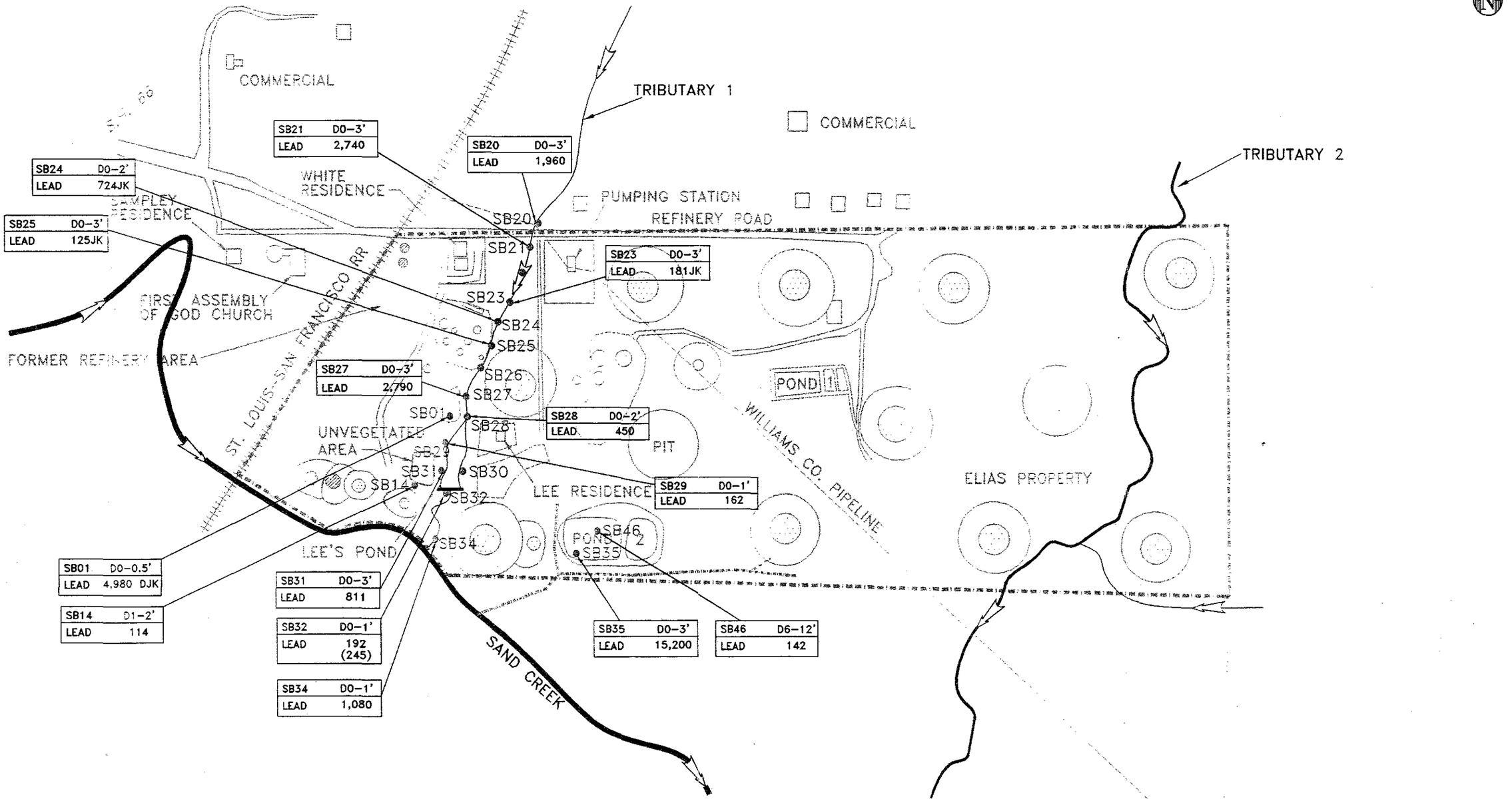
FIGURE 4-1 ELEVATED ORGANICS IN SEDIMENT AND SOIL
WILCOX REFINERY
BRISTOW, OKLAHOMA

TDD# S06-98-03-0009 | Date: MARCH 31, 1999

PAN# 052601SFXX | P.M.: T. BEER



NOTES
ALL CONCENTRATIONS ARE LISTED IN MILLIGRAMS PER KILOGRAM (mg/kg). FOR A SUMMARY OF INORGANIC ANALYTICAL RESULTS, SEE TABLE 4–2. D5.5–6.5' – DEPTH OF SAMPLE COLLECTION IN FEET BELOW GRADE. (245) – DUPLICATE RESULT.

LEGEND

- FORMER TANK LOCATION
- LEVELED BERM
- BERM
- BUILDING
- EXISTING TANKS
- I.T.I. BOUNDARY
- DRAINAGE DITCH
- SOIL BORING LOCATION
- DIRECTION OF FLOW

BASE MAP SOURCE: ROY F. WESTON INC., ESI REPORT, MARCH, 1997, FROM ACE AERIAL PHOTO, 1966.

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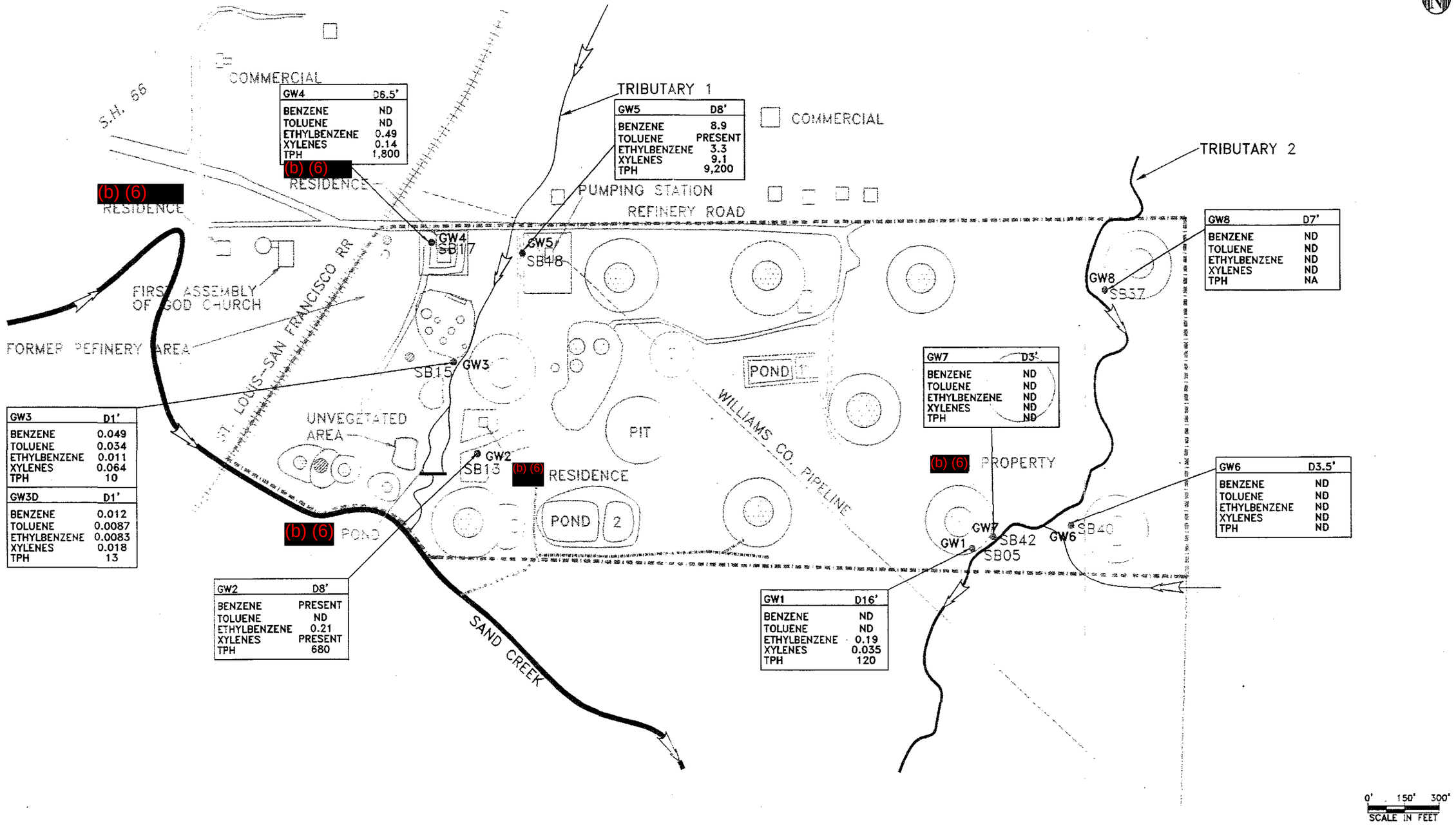
FIGURE 4–2 ELEVATED INORGANICS IN SEDIMENT AND SOIL
WILCOX REFINERY
BRISTOW, OKLAHOMA

TDD# S06–98–03–0009 Date: MARCH 31, 1999

PAN# 052601SFXX P.M.: T. BEER



NOTES
ALL CONCENTRATIONS ARE LISTED IN MILLIGRAMS PER LITER. (mg/L).
FOR A SUMMARY OF GROUND WATER RESULTS, SEE TABLE 4-3.
D7.5' – DEPTH OF SAMPLE COLLECTION IN FEET BELOW GRADE.
NA – NOT ANALYZED
ND – NOT DETECTED.
PRESENT – IDENTIFIED BELOW THE DETECTION LIMIT.
BTEX– BENZENE, TOLUENE, ETHYLBENZENE AND XYLENES.
TPH – TOTAL PETROLEUM HYDROCARBONS.

LEGEND	
FORMER TANK LOCATION	SITE BOUNDARY
CUT/LEVELED BERM	POND
BERM	DRAINAGE DITCH
BUILDING	GW1 GROUND WATER SAMPLE
EXISTING TANKS	SOIL BORING LOCATION
	DIRECTION OF FLOW

BASE MAP SOURCE: ROY F. WESTON INC., ESI REPORT, MARCH, 1997, FROM ACE AERIAL PHOTO, 1966.

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FIGURE 4-3 BTEX AND TPH IN GROUND WATER
WILCOX REFINERY
BRISTOW, OKLAHOMA

TDD# S06-98-03-0009	Date: MARCH 31, 1999
PAN# 052601SFXX	P.M.: T. BEER

5 ARARs and TBCs

The NCP spill response program addresses only imminent and substantial threats to navigable waters of the United States. Risk assessment and long-term human health or ecological risks from documented site contamination are beyond the scope of this program. Threat to navigable waters at the Wilcox refinery site is determined by comparing site chemical data with Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered materials (TBCs).

ARARs refer to federal or state laws and environmental protection requirements that are legally applicable to the investigation site. TBCs are non-promulgated advisories or guidance for the protection of human health and the environment that are generally not enforceable. The potential regulatory requirements for the site include federal environmental laws administered by the U.S. EPA and other federal agencies, and laws administered by the State of Oklahoma. ARARs and TBCs are typically categorized as chemical-, location-, or action-specific criteria. Chemical-specific criteria are usually health- or risk-based values that establish the acceptable concentration of a chemical for each medium. Location-specific requirements are restrictions placed upon the presence of a hazardous substance or the conduct of activities based solely on site location. Action-specific requirements are technology- or activity-based restrictions placed on remedial actions. Only chemical-specific ARARs and TBCs are discussed below due to the preliminary nature of this investigation.

This section presents a qualitative evaluation of the significance of site data by comparing numerical criteria from chemical-specific ARARs and TBCs identified for the site to maximum detected concentrations in the media tested at the Wilcox site.

5.1 Regulatory Criteria

To date, no ARARs have been identified for the site. The TBCs identified for the site are from the Resource Conservation and Recovery Act (RCRA) hazardous waste characteristics in the Code of Federal Regulations (CFR) Title 40, Part 261 (40 CFR 261); RCRA Land Disposal Restrictions (LDRs) (40 CFR 268); Oklahoma Corporation Commission (OCC) Underground Storage Tank (UST) Program; and TNRCC Risk Reduction Standards (RRS) in the Texas Administrative Code (TAC), Chapter 35, Subchapter S, Section 335. Site-specific analytical data for all analytes detected in site media were compared to the identified TBCs as applicable for each medium. TBCs for organic compounds are listed in Table 5-1 and TBCs for inorganic analytes are in Table 5-2.

According to RCRA in 40 CFR 261, Subpart C, four characteristics can be used to determine if a waste is hazardous: ignitability, corrosivity, reactivity, and toxicity. The characteristics most applicable for the evaluation of site data at Wilcox are toxicity for metals data and corrosivity for pH data. Toxicity is determined by analysis for hazardous constituents in an extract or leachate of the waste using the toxicity characteristic leaching procedure (TCLP) (40 CFR 261, Subpart C, Appendix II). The concentration of detected total metals results in site samples that can be compared to 20 times their respective TCLP criteria for an evaluation of hazard. The factor of "20 times TCLP criteria" is based on the extraction methodology of the TCLP. The weight of extract fluid used is 20 times the weight of sample. If it is assumed that the metal of concern can be completely extracted from the waste sample, an extremely conservative assumption, the metal concentration in the leachate cannot be greater than one-twentieth the metal concentration in the solid sample. Thus, total metals data can be classified as not of concern if it is less than the TBC factor of 20 times TCLP criteria (Table 5-2). RCRA hazardous corrosivity criteria are exceeded if pH is less than or equal to 2, or greater than or equal to 12.5 (Table 5-2).

RCRA LDRs are treatment standards for the allowable land disposal of restricted wastes. The listed constituent concentrations may not be exceeded in the waste or treatment residuals. RCRA LDRs are considered TBCs at Wilcox refinery for an initial evaluation of on-site treatment requirements (Table 5-1). The State of Oklahoma OCC UST Program has levels of chemical constituent concentrations that confirm a release to native soils and/or ground water. The OCC UST program release concentrations and corrective action levels are considered TBCs at Wilcox for BTEX compounds and TPH (Table 5-1).

Several TNRCC RRSs are identified as TBCs: the soil/air and ingestion standard for residential use (SAI-Res), the ground water protection standard for residential use (GWP-Res), and ground water standards.

- SAI-Res is the concentration in residential soil that is protective of human health considering cross-media contamination of air, and human ingestion and inhalation pathways from contaminated surface and subsurface soil;
- GWP-Res is the concentration in residential soil assumed protective of ground water considering cross-media contamination of ground water from contaminated subsurface soil; and
- Ground water standards are the allowable concentrations of a contaminant in ground water for residential exposure conditions.

As required by the RRS, the Federal Primary Drinking Water Regulations, Code of Federal Regulations (CFR) 141, Maximum Contaminant Levels (MCLs) should be used to evaluate ground water contamination. For the constituents detected at this site, the ground water standards are the same as the MCLs. Additionally, as allowed by the RRSs, other criteria can be used to evaluate constituents that may present an objectionable characteristic (e.g., bad taste and odor) or can make a natural resource unfit for use.

The following sections discuss the site-specific analytical data and TBCs for 1) oily waste and surface soil (less than 1 foot bgs) from the ESI, and 2) subsurface soil (more than 1 foot bgs), ground water, and surface water from the START field investigation. The maximum concentrations detected at Wilcox refinery are compared to the identified chemical-specific TBCs.

5.1.1 Oily Waste and Surface Soil

Analyte concentrations detected in oily waste and surface soil samples collected during the ESI (Table 2-2) were compared to RCRA LDRs or a factor of 20 times TCLP criteria; Oklahoma UST action and cleanup levels, and the TNRCC GWP-Res and SAI-Res standards (Tables 5-1 and 5-2). TBC values were available for six of the eight organic analytes detected significantly above background concentrations in oily waste or surface soil. Phenanthrene, pyrene, and TPH were detected in oily waste at concentrations exceeding one or more of their respective TBC values (Table 2-2). No organic analytes detected in surface soil exceed any of their respective TBC values.

TBC values were available for eight of the 16 metals and cyanide detected significantly above background concentrations in oily waste and surface soil: antimony, arsenic, barium, beryllium. lead, mercury, selenium, and silver. Unlike metals such as magnesium and iron,

which are essential nutrients at low levels, these eight metals can be toxic at low levels. Of the heavy metals, antimony, arsenic, beryllium, and lead were detected in oily waste at concentrations exceeding one or more of their respective TBC values. Lead was detected in surface soil at concentrations exceeding one or more identified TBC values (Table 2-2).

5.1.2 Subsurface Soil

Analyte concentrations detected in subsurface soil samples collected by START for this investigation were compared to RCRA LDRs, Oklahoma UST action and cleanup levels, and the TNRCC GWP-Res and SAI-Res standards (Table 5-1).

Wastes related to the petroleum refining industry have land disposal restriction TBCs for treatment residuals with specific constituents. RCRA LDRs exist for 11 of the 22 organic analytes detected, including TPH. The following nine compounds exceeded RCRA LDRs for refinery waste: ethylbenzene, toluene, xylenes, anthracene, benzo(a)anthracene, benzo(a)pyrene, chrysene, phenanthrene, and pyrene.

The OCC has action and cleanup levels for BTEX compounds and TPH in soil at UST sites. Maximum site concentrations of all BTEX and TPH constituents at Wilcox refinery exceed one or both OCC standards.

Pre-calculated GWP-Res and SAI-Res values exist for 11 of the 22 organic analytes detected, not including TPH (Table 5-1). Of these 11 compounds, only benzene was detected in subsurface soil at a concentration exceeding both RRSs. Ethylbenzene, toluene, xylenes, fluoranthene, fluorene, and pyrene were detected at concentrations exceeding their GWP-Res values.

RCRA TCLP criteria exist for seven of the 21 metals detected in subsurface soil at Wilcox refinery. Potentially hazardous concentrations exceeding 20 times TCLP criteria were only detected for lead. For presentation purposes, exceedances of any TBC and total metals results that exceed 20 times TCLP criteria are highlighted in Table 5-2.

Pre-calculated GWP-Res and SAI-Res standards exist for 11 of the 23 metals detected in subsurface soil samples: antimony, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, nickel, selenium, and silver (Table 5-2). Three of these metals (arsenic, beryllium, and lead) were detected at concentrations exceeding both RRSs. In summary, the contaminants in subsurface soil include all BTEX compounds and TPH, eight PAHs (anthracene, benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, fluorene, phenanthrene, and pyrene), and eight metals but most significantly lead.

5.1.3 Ground Water

Organic analyte concentrations detected in ground water samples were compared to Texas RRSs, maximum concentrations in ground water for residential exposure, and soil TBCs (Table 5-1). Texas RRSs for ground water only exist for benzene, ethylbenzene, and toluene, and maximum site concentrations for benzene and toluene exceed these TBCs. The maximum benzene concentration in ground water also exceeds most soil TBCs. Metals were not analyzed in water samples at Wilcox refinery.

5.2 Contaminants of Concern

Based on their presence at concentrations exceeding one or more identified TBCs, the contaminants of concern (COCs) associated with various media at the Wilcox refinery site are:

- ESI oily waste: phenanthrene, pyrene, TPH, antimony, arsenic, beryllium, and lead (Weston 1997);
- ESI surface soil: lead (Weston 1997);
- Sediment: none;
- Subsurface soil: benzene, ethylbenzene, toluene, xylenes, anthracene, benzo(a)-anthracene, benzo(a)pyrene, chrysene, fluoranthene, fluorene, phenanthrene, pyrene, gasoline, TPH, antimony, arsenic, beryllium, cadmium, chromium, lead, mercury, and nickel;
- Ground water: benzene and toluene, and in addition TPH presents an objectionable taste and odor making shallow ground water at the site unfit for use; and
- Surface Water: none.

Table 5-1

**EXAMPLE REGULATORY CRITERIA
TO BE CONSIDERED MATERIALS, ORGANICS
WILCOX REFINERY, BRISTOW, OKLAHOMA**

Analyte	Site Max.[1] Soil (mg/kg)	Site Max.[1] Water (mg/L)	RCRA[2] LDRs (mg/kg)	Oklahoma UST[3] Action Level (ppm)	Oklahoma UST[4] Cleanup Level 2 (ppm)	Texas RRSs[5] GWP-Res (mg/kg)	Texas RRSs[6] SAI-Res (mg/kg)
Volatiles							
Benzene	**2.2 JH**	**8.9 (0.005)[7]**	14	0.5	5	0.5	1.33
Ethylbenzene	**670**	0.087 (0.7)[7]	14	15	150	70	11,400
Toluene	**410**	3.3 (1.0)[7]	14	40	400	100	3,580
Xylenes	**2,600**	9.1 (--)[7]	22	200	1,000	1,000	54,700
Semi-Volatiles							
Acenaphthene	0.78	--	--	--	--	219	13,400
Acenaphthylene	<2,500	--	--	--	--	--	--
Anthracene	**700**	--	28	--	--	1,100	59,100
Benzo(a)anthracene	**2,800**	--	20	--	--	--	--
Benzo(b)fluoranthene	320	--	--	--	--	--	--
Benzo(k)fluoranthene	580	--	--	--	--	--	--
Benzo(a)pyrene	**920**	--	12	--	--	--	--
Benzo(ghi)perylene	<620	--	--	--	--	--	--
Chrysene	**2,800**	--	15	--	--	--	--
Dibenz(ah)anthracene	<620	--	--	--	--	--	--

Key at end of table.

Table 5-1 (Cont.)

EXAMPLE REGULATORY CRITERIA
TO BE CONSIDERED MATERIALS, ORGANICS
WILCOX REFINERY, BRISTOW, OKLAHOMA

Analyte	Site Max.[1] Soil (mg/kg)	Site Max.[1] Water (mg/L)	RCRA[2] LDRs (mg/kg)	Oklahoma UST[3] Action Level (ppm)	Oklahoma UST[4] Cleanup Level 2 (ppm)	Texas RRSs[5] GWP-Res. (mg/kg)	Texas RRSs[6] SAI-Res. (mg/kg)
Semi-Volatiles (Cont'd)							
Fluoranthene	**4,000**	--	--	--	--	146	11,000
Fluorene	**540**	--	--	--	--	146	9,600
Indeno(1,2,3-cd)pyrene	<250	--	--	--	--	--	--
1-Methylnaphthalene	17	--	--	--	--	--	--
2-Methylnapththalene	7,000	--	--	--	--	--	--
Naphthalene	<2,500	--	42	--	--	146	4,910
Phenanthrene	**11,000**	--	34	--	--	--	--
Pyrene	**2,500**	--	36	--	--	110	8,020
Hydrocarbons							
Gasoline (C6-C10)	**8,600**	**3,300 (--)[7]**	--	--	250[8]	--	--
TPH (C6-C28)	**280,000**	**9,200 (--)[7]**	--	50	500	--	--

Key at end of table.

Table 5-1 (Cont.)

Key:
Blank spaces denote no data or no standards available

Shaded and **bold** results exceed one or more TBCs

1 - Maximum site concentration in soil and water
2 - Resource Conservation and Recovery Act (RCRA) land disposal restrictions (LDRs), 40 CFR 268.43
3 - Oklahoma Corporation Commission (OCC), Underground Storage Tank (UST) Program
4 - OCC UST Cleanup Level 2
5 - Texas Risk Reduction Standard (RRS), Ground Water Protection (GWP) for Residential Use
6 - Texas RRS Soil/Air and Ingestion (SAI) Standard for Residential Use, TAC 335.568
7 - Texas RRS Ground Water (GW), maximum concentration in GW for residential exposure conditions
8 - State of Washington, Class 3 soil suitable for disposal on site

mg/kg - Milligrams per kilogram
mg/L - Milligrams per liter
ppm - Parts per million
TPH - Total petroleum hydrocarbons

Table 5-2

EXAMPLE REGULATORY CRITERIA
TO BE CONSIDERED MATERIALS, INORGANICS
WILCOX REFINERY, BRISTOW, OKLAHOMA

Analyte	Site Max.[1] Soil (mg/kg)	RCRA[2] 20 x TCLP (ppm)	Texas RRSs[3] GWP-Res (mg/kg)	Texas RRSs[4] SAI-Res (mg/kg)
Metals				
Aluminum	11,300			
Antimony	**1.4**		0.6	110
Arsenic	**11.4**	100	5	0.366
Barium	171		200	19,100
Beryllium	**0.81**		0.4	0.149
Cadmium	**2.8**	20	0.5	137
Calcium	18,400			
Chromium	**15.2**	100	10	391
Cobalt	9.8			
Copper	122			
Iron	37,300 JK			
Lead	**15,200**	100	1.5	500
Magnesium	9,910			
Manganese	1,100 JL			
Mercury	**0.39**	4.0	0.2	82.3
Nickel	**183**		10	1,560
Potassium	1,820 JK			
Selenium	1.1	20	5	1,370
Silver	2.3	100	18.3	1,370
Sodium	4,690 JK			
Thallium	0.54			
Vanadium	27.7			
Zinc	83.8 JK			
pH	2.3 to 9.5	<2 or >12[5]		

Key on next page.

Table 5-2 (Cont.)

Key:

Results that are shaded and **bold** exceed one or more TBCs
Blank spaces denote no data or no standards available

1 - Maximum site concentration in soil
2 - Derived criteria for solid waste from 20 times RCRA Toxicity Characteristic Leaching Procedure (TCLP), 40 CFR 261.24
3 - Texas Risk Reduction Standard (RRS), Groundwater Protection for Residential Use, TAC 335.568
4 - Texas RRS, Soil/Air and Ingestion (SAI) Standard for Residential Use, TAC 335.568
5 - RCRA hazardous waste criteria for corrosivity, 40 CFR 261.22

mg/kg - Milligrams per kilogram
ppm - Parts per million

6 Findings

The objectives of the site assessment under the NCP were to document the extent of spill impacts, determine threat to navigable waters of the United States, and evaluate the necessity for removal action. The following findings are based on site activities conducted by START in 1998, and on the evaluation of analytical data from this investigation and from the previous ESI (Weston 1997):

1. The Wilcox refinery site is a former oil refinery and tank farm of approximately 98 acres located to the northeast of Bristow, in Creek County, Oklahoma. The refinery and associated tank farm operated from the 1920s until the 1960s, when the site was abandoned and most steel structures were salvaged and removed. The site is also bordered to the northwest and west by former refinery and tank farm sites. Currently, the site has four owners: (b) (6) (79-acre tank farm), (b) (6) (b) (6) (18-acre former refinery), (b) (6) (3.6-acre lot), and Sun Oil Company (1.1-acre active pipeline ROW and former pumping station area).

2. The Wilcox site has a number of refinery waste source areas of concern including: a backfilled oily waste pond (Pond 1); a breached settlement pond (Pond 2); a backfilled "oily waste pit"; an unvegetated former pond apparently backfilled with solid refinery waste; two backfilled ponds on the (b) (6) property; ten former large aboveground storage tank bermed areas affected by minor tank bottom sludge; numerous areas of affected soil on the refinery area and former pumping station; and solid and liquid tarry waste that has directly affected the lower reaches of Tributary 1.

3. EPA completed a Site Identification form on June 7, 1994, and ODEQ completed a PA for the Wilcox site and the adjacent refinery and tank farm sites on December 15, 1994. An ESI was completed by Weston for the ODEQ in March 1997. Field work for the NCP site assessment was conducted by START from April to August 1998.

4. ESI results indicated high concentrations of TPH, lead, and some PAHs in oily waste at numerous locations on site, and high concentrations of lead in the unvegetated area soil, so these waste sources were not sampled further by START for this NCP site assessment.

5. Subsurface geologic conditions at the site generally consist of a thin (0 to 10 feet) brown, silty sand layer above weathered red sandstone. Seasonal perched water is present in thin lenses above the sandstone, but the shallowest saturated sandstone aquifer on site is estimated at 45 to 60 feet bgs. Rainfall runoff and shallow subsurface ground water flow follow the topography south and east or west toward Tributaries 1 and 2 on site, and toward Sand Creek to the south.

6. START collected 55 subsurface soil samples, eight ground water samples, four surface water samples, two sediment samples, and 12 field QC samples. Samples were submitted for laboratory analysis of volatile BTEX compounds, semi-volatile PAHs, TPH, metals, and pH.

   - Subsurface soil sample results confirm the presence of significant concentrations of all BTEX compounds, eight PAH compounds including benzo(a)pyrene, seven metals but most significantly lead, and TPH. All these contaminants of concern appear to be related to the disposal and abandonment of refinery waste on site.

   - Sediment sampling results and shallow subsurface soil sampling results in the dry stream bed of Tributary 1 and Pond 2 confirm the presence of elevated concentrations of four PAH compounds including benzo(a)pyrene, as well as lead, and TPH. Attribution of metals contamination in the Tributary 1 stream bed is problematic due to significant upstream sources of lead contamination. However, lead in Pond 2 sediment, and PAHs and TPH in the lower reaches of Tributary 1 are significant sources of potential surface water contaminant migration on site.

   - Ground water sampling results for organic compounds detected elevated concentrations of BTEX compounds and TPH at several distinct locations on site. Attempts to define plume boundaries proved unsuccessful and the potential shallow ground water to surface water migration pathway at sample sites GW1, GW2, GW4, and GW5, appear insignificant. The GW3 water sample was from shallow saturated soil adjacent to Tributary 1 and is indicative of contaminated soil pore space water in contact with surface water.

   - BTEX compounds and TPH were not detected in surface water samples. Samples were collected during dry conditions with no flow in Tributaries 1 and 2. START observed visible sheens on on-site runoff after a storm event in April 1998; however, no release to surface water was recorded.

   - The laboratory data package was evaluated using standard EPA validation procedures. Numerous data were qualified as estimated and a total of 55 metals data points were rejected mainly due to poor spike recoveries. Further evaluation of data quality was performed using PARCC parameters, with the overall usability of the data being acceptable and the analytical completeness ranging from 96% for metals to 100% for BTEX and PAHs.

7. Approximately 73,000 cubic yards of oily waste and contaminated soil, and 3,000 gallons of liquid waste was identified at 18 source areas on the Wilcox refinery site. This waste volume estimate does not include known areas of contaminated ground water on site, or the quantity of oily liquid observed entering the lower reaches of Tributary 1 from the (b) (6) property via a buried pipeline. In addition, the volume of

contaminated soil on the former refinery site and pumping station area in particular are unknown, and can only be determined by a systematic and comprehensive drilling and sampling program.

8. A total of five people live on site, at the (b) (6) residence (two adults), and (b) (6) residence (two adults and one child). Based on limited surface and subsurface soil, and perched ground water sampling results, both residences are located on significantly contaminated waste source areas. The (b) (6) residence is a former office at the main gate truck fuel loading facility and the (b) (6) residence is built on a backfilled refinery pond surrounded by other waste sources. Relocation or removal action at both residences is warranted.

7 References

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Appendix A
Soil Boring Logs

DRILLING LOG OF WELL/BORING NO. SB-X

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Exploratory boring southeast of former sludge Pond 1.
Date Started/Finished: 27 April 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 6
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 0.0 Final: ▼ ____
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.								
			ground surface (gs)						
1	*Hydrated Bentonite Seal.*		0.4 SP - Uniformly brown silty fine-medium SAND, subangular, moderate sorting, clast supported (feldspar, quartz, and trace rock fragments), wet. Noted trace rootlets throughout.						No analytical samples were collected at this exploratory boring.
2			SW - Mottled orange-red-brown fine-medium SAND with trace fines, subangular, well sorted, clast supported (feldspar & quartz), moist. Noted trace natural organic staining at 2-feet bgs.			4.0			
3									
4									
5						2.0			
6			6.0 Refusal at 6-feet bgs. End of Boring.						Due to 4-inches of rainfall on 26 April 1998, ground surface was saturated with water.
7									
8									
9									
10									

DRILLING LOG OF WELL/BORING NO. SB-01

Project/Location: Wilcox Refinery / Bristow, Oklahoma

Boring Location: Boring located on (b) (6) property, west of (b) (6) Pond.

Date Started/Finished: 27 April 1998/

Drilling Contractor: Ecology & Environment, Inc.

Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 11

Ground Elevation (feet above): Unknown

Inner Casing Elevation (TOC): N/A

Groundwater Depth (feet BGS):

First Encountered: ▽ 0.0 Final: ▼

Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location. ▽		*ground surface (gs)*						
1–2	*Hydrated Bentonite Seal*		SP - Mottled to variable orange-brown-black fine to medium SAND with trace fines, subangular, well sorted, clast supported (feldspar & quartz), wet. Noted black staining with strong petroleum odor throughout.			4.0			Collected Sample SB01-06 (0-0.5 feet bgs).
4.0			SP - Variably brown-red grading to red, fine-medium SAND with trace fines, subangular, well sorted, clast supported (feldspar & quartz), wet. Noted black staining with strong petroleum odor throughout.			3.0			
7.0			SP - Variably brown-red-orange-black, fine-medium SAND with trace fines, subangular, well sorted, clast supported (feldspar & quartz), wet. Observed trace clay lenses throughout.			3.2			
10.0			Noted black staining with strong petroleum odor throughout.						Collected Sample SB01-1011 (10-11 feet bgs). Due to 4-inches of rainfall on 26 April 1998, ground surface was saturated with water. Petroleum sheen on water was noted in the vicinity of the boring. PID/FID readings were unreliable due to faulty equipment.
10.2			CH - Mottled light gray-red silty CLAY, high plasticity, firm cohesive strength, matrix supported, sharp upper contact, dry. Noted slight odor, no staining observed. No recovery.						
11.0			Refusal at 11-feet bgs. End of Boring.						
12–15									

DRILLING LOG OF WELL/BORING NO. SB-02

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Southeast of Pond 1.
Date Started/Finished: 01 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 2.1
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼ ____
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
	Hydrated Bentonite Seal		SM - Uniformly brown SILTY SAND, subangular, moderately sorted, matrix supported (feldspar & quartz), moist.					0	
0.9									
1			SP - Mottled orange-red SAND with trace fines, subangular, well sorted, clast supported (feldspar), moist.			2.1		0	Collected Sample SB02-12 (1-2 feet bgs).
2			2.1 Refusal at 2.1 feet. End of boring.					0	
3									
4									
5									

DRILLING LOG OF WELL/BORING NO. SB-03

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: South of Pond 1.
Date Started/Finished: 01 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 1.5
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
	Hydrated Bentonite Seal		SM - Uniformly brown SILTY SAND, fine, subangular, moderately sorted, matrix supported (quartz & organics), dry.					0	
			0.6 SP - Mottled orange-red SAND with trace fines, subangular, well sorted, clast supported (feldspar & quartz), moist.			1.5		0	
1			1.5 Refusal at 1.5 feet. End of boring.					0	Collected Sample SB03-01015 (1-1.5 feet bgs).
2									
3									
4									
5									

DRILLING LOG OF WELL/BORING NO. SB-04

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Southwest of Pond 1.
Date Started/Finished: 01 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 5
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼ ____
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1	*Hydrated Bentonite Seal*		SM - Uniformly brown SILTY SAND, fine, angular, moderately sorted, matrix supported (quartz & organics), dry.					0	
1.8									
2			SP - Mottled orange-red SAND with trace fines, fine to medium, subangular, well sorted, matrix supported (feldspar & quartz), moist.			4.0		0	
3								0	
4									
4.0			SP - Mottled orange-red, fine to medium SAND with 20% fines, subangular, well sorted, matrix supported (feldspar & quartz), moist. Noted trace petroleum staining with slight petroleum odor at 4-feet bgs. Refusal at 5.0 feet. End of boring.			1.0		0.4	Collected Sample SB04-0405 (4.0 - 5.0 feet bgs).
5									
5.0									
6									
7									
8									
9									
10									

DRILLING LOG OF WELL/BORING NO. SB-05

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Southeast end of property.
Date Started/Finished: 01 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 20
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 15.5 Final: ▼
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1–3	*Hydrated Bentonite Seal*		SM - Uniformly brown SILTY SAND, fine, subangular, moderately sorted, matrix supported, moist.			3.0		40	Collected Sample SB05-0102 (1.0 - 2.0 feet bgs).
3.0			Noted trace black oil-like product throughout.						
4.0			No recovery.						
4–8			SW/SM - Uniformly gray-brown SILTY/CLAYEY SAND, fine, subangular, well sorted, low plasticity, firm cohesive strength, matrix supported, moist. Upper contact - gradational.			4.0		20	Collected Sample SB05-0405 (4.0 - 5.0 feet bgs).
8.0			Noted slight staining throughout with petroleum odor.						
8–12			MLS - Mottled orange gray SANDY SILT with some CLAY (~25%), low plasticity, soft cohesive strength, moist.			4.0		5	
12.0			Noted strong petroleum odor throughout.						
12–15			MLS - Mottled orange gray fine SANDY SILT with some CLAY (~25%), low plasticity, soft cohesive strength, moist grading wet. First water encountered at 15.5 feet bgs.			3.0		5	Collected Sample SB05-1415 (14 - 15 feet bgs).
15.0			Noted sheen in water with slight petroleum odor throughout.						
16.0			No recovery.						
16–18			MLS - Mottled orange gray fine SANDY SILT with some CLAY (~25%), low plasticity, soft cohesive strength, saturated.			2.0		300	
18.0			Noted sheen and strong petroleum odor throughout.						
20.0			No recovery.						
			End of boring at 20 feet bgs.						

DRILLING LOG OF WELL/BORING NO. SB-06

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: South-central tank berm area.
Date Started/Finished: 02 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 2.2
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼ ____
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
0	*Hydrated Bentonite Seal*		ML - Uniformly brown-red, fine SANDY SILT, medium plasticity, loose cohesive strength, matrix supported, moist.					0	
1						2.2		0	Collected Sample SB06-0102 (1.0 - 2.0 feet bgs).
2			2.0 SP - Mottled orange-red SAND with trace fines, subangular, well sorted, clast supported (feldspar & quartz), moist. 2.2 Refusal at 2.2 feet bgs. Noted weathered arkosic sandstone in foot of macro-sampler. End of boring.						
3									
4									
5									

DRILLING LOG OF WELL/BORING NO. SB-07

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: West of oily waste 'Pit'.
Date Started/Finished: 02 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 5
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1	*Hydrated Bentonite Seal*		SM - Uniformly brown SILTY SAND, fine, subangular, moderately sorted, matrix supported, moist.			4.0		0	
3.0			SP - Mottled orange-red SAND with trace fines, subangular, well sorted, clast supported (feldspar & quartz), moist. Upper contact - sharp.						
4.0			SC - Mottled orange-gray-brown CLAYEY fine SAND, subangular, moderately sorted, medium plasticity, soft cohesive strength, clast supported, moist.			1.0		0	Collected Sample SB07-0405 and duplicate SB07D-0405 (4.0 - 5.[illegible] bgs).
5.0			Refusal at 5.0 feet bgs. End of boring.						
6									
7									
8									
9									
10									

DRILLING LOG OF WELL/BORING NO. SB-08

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Southwest of oily waste 'Pit'.
Date Started/Finished: 02 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 2
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1	*Hydrated Bentonite Seal*		SP - Mottled orange-brown SAND with trace fines, subangular, well sorted, clast supported (feldspar & quartz), dry grading to moist.			2.0		0	Collected Sample SB08-0102 (1.0 - 2.0 feet bgs).
2			2.0 Refusal at 2.0 feet bgs. End of boring.						
3									
4									
5									

DRILLING LOG OF WELL/BORING NO. SB-09

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: South of oily waste 'Pit'.
Date Started/Finished: 02 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 2.2
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
0	*Hydrated Bentonite Seal*		SM - Mottled brown-orange SILTY SAND, fine, subangular, moderately sorted, matrix supported, moist.			2.2		0	Noted hard black asphalt material adjacent to boring location.
1									Collected Sample SB09-0102 (1.0 - 2.0 feet bgs).
2			2.0 WR - Uniformly red-brown weathered arkosic SANDSTONE. 2.2 Refusal at 2.2 feet bgs. End of boring.						
3									
4									
5									

DRILLING LOG OF WELL/BORING NO. SB-10

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: West of (b) (6) residence.
Date Started/Finished: 02 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 4.3
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
0	*Hydrated Bentonite Seal*		SM - Uniformly brown SILTY SAND, fine, subangular, moderately sorted, matrix supported, moist.			4.0		0	Collected Sample SB10-0304 (3.0 - 4.0 feet bgs).
4.0			WR - Uniformly red weathered arkosic SANDSTONE.			0.3		0	
4.3			Refusal at 4.3 feet bgs. End of boring.						

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DRILLING LOG OF WELL/BORING NO. SB-11

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: ~120-ft. north of (b) (6) residence.

Date Started/Finished: 02 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 3
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
0	*Hydrated Bentonite Seal*		SM - Uniformly brown SILTY SAND, fine, subangular, moderately sorted, matrix supported, moist.			3.0		0	
1									
2								0	Collected Sample SB11-0203 (2.0 - 3.0 feet bgs).
2.8			SW - Uniformly tan, fine to medium SAND with trace fine GRAVEL, subangular, well sorted, matrix supported, moist. Upper contact - sharp.						
3			Refusal at 3.0 feet bgs. End of boring.						
4									
5									

DRILLING LOG OF WELL/BORING NO. SB-12

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Southwest corner of Site.
Date Started/Finished: 02 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 9
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 8.9 Final: ▼ ____
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1	*Hydrated Bentonite Seal*		MLS - Uniformly brown-red SANDY SILT with trace CLAY (~10%), medium plasticity, soft cohesive strength, moist.					0	Collected Sample SB12-0102 (1.0 - 2.0 feet bgs).
2						3.0		0	
3			3.0 No recovery.						
4			4.0 SP - Mottled gray-orange-tan, fine SAND with trace fines, subanguiar, well sorted, clast supported , moist grading to wet.					0	
5									
6						4.0			
7								0	
8									
9	▽		9.0 Refusal at 9.0 feet bgs. End of Boring.			1.0		0	Collected Sample SB12-0809 (8.0 - 9.0 feet bgs).
10									

DRILLING LOG OF WELL/BORING NO. SB-13

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Former pond, South of Lee's residence.
Date Started/Finished: 02 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 10
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 8.0 Final: ▼
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1	*Hydrated Bentonite Seal*		SP - Mottled brown-red SAND with trace fines, subangular, well sorted, clast supported, moist.			3.3		0	Collected Sample SB13-0102 (1.0 - 2.0 feet bgs).
3.3			No recovery.						
4.0			SP - Mottled orange-brown SAND with trace fines, subangular, well sorted, clast supported, moist. Noted slight petroleum odor.					0	
6.5						3.5		0	
7.5			SM - Uniformly brown SILTY fine SAND with trace CLAY (~5%), subangular, moderately sorted,					50	Collected Sample SB13-6575 (7.5 feet bgs).
8.0 ▽			matrix supported, moist grading to wet. Noted strong petroleum odor throughout.						
			No recovery.			2.0		60	
10.0			SM - Uniformly brown SILTY fine SAND with trace CLAY (~5%), subangular, moderately sorted, matrix supported, saturated. End of boring at 10.0 feet bgs.						

DRILLING LOG OF WELL/BORING NO. SB-14

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: South of White's unvegetated area.

Date Started/Finished: 03 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 11
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 4.5 Final: ▼
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.								
			ground surface (gs)						
1–3	*Hydrated Bentonite Seal*		SM - Uniformly brown SILTY fine SAND, subangular, moderately sorted, matrix supported, dry. Noted anaerobic decay odor.			3.5		3	Collected Sample SB14-0102 (1.0 - 2.0 feet bgs).
			3.5						
4			4.0 No recovery.						
5–7			SC - Mottled brown-red CLAYEY SAND grading to CLAY, moderate sorting, matrix supported, moist with wet zone at 4.5 feet bgs. Noted strong anaerobic decay odor.			4.0		20	Collected Sample SB14-0506 (5.0 - 6.0 feet bgs).
8			8.0						
9–10			CH - Mottled orange-tan CLAY with trace SILT and fine SAND, high plasticity, firm cohesive strength, moist. Noted slight anaerobic decay odor.			3.0		4	
11			11.0 End of boring at 11 feet bgs.						
12–15									

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DRILLING LOG OF WELL/BORING NO. SB-15

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: ~450-ft. south of White's residence.
Date Started/Finished: 03 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 3.1
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 1.0 Final: ▼
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
	Hydrated Bentonite Seal		FILL - Uniformly black CINDER or ASH with SANDY GRAVEL texture, poorly sorted, clast supported, moist grading to wet at 1 foot bgs. Noted slight petroleum odor.			3.1		40	Collected Sample SB15-0001 (0.0 - 1.0 feet bgs).
			3.1 Refusal at 3.1 feet bgs. End of boring. Noted weathered sandstone in foot of macro-sampler.						

1 2 3 4 5

DRILLING LOG OF WELL/BORING NO. SB-16

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Northwest of White's small AST.
Date Started/Finished: 03 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 6.5
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 4.0 Final: ▼ ____
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.								
	Hydrated Bentonite Seal		*ground surface (gs)*						
1			MLS - Uniformly brown fine SANDY SILT with trace organic matter (~5%), low plasticity, loose cohesive strength, moist. Noted trace plant matter throughout.					0	
1.1									
2			SP - Mottled brown-orange, fine to medium SAND with trace fines, subangular, well sorted, clast supported, moist. Upper contact - sharp. Noted slight petroleum odor at 2.8 feet bgs. No recovery.			2.8		0	
2.8									
3									
4									
4.0			SM - Uniformly brown with black staining noted throughout, SILTY fine SAND with trace CLAY (~5%), subangular, moderately sorted, matrix supported, wet. Noted petroleum odor.			2.5		20	Collected Sample SB16-0506 (5.0 - 6.0 feet bgs).
5									
6									
6.1			SP - Uniformly white, fine to coarse SAND with trace SILT and GRAVEL, angular to subangular, poorly sorted, clast supported, slight cementation, moist. Upper contact - sharp. Refusal at 6.5 feet bgs. End of boring. Noted weathered sandstone in foot of macro-sampler.						
6.5									
7									
8									
9									
10									

DRILLING LOG OF WELL/BORING NO. SB-17

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: West of White's residence.
Date Started/Finished: 03 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 11.5
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 6.3 Final: ▼ ____
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL / BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*					
0	*Hydrated Bentonite Seal*		SM - Uniformly light brown, SILTY SAND, subangular, well sorted, clast supported (feldspar & quartz), dry.		4.0		1	Collected Sample SB17-0102 and duplicate SB17D-0102 (1.0 - 2.0 feet bgs).
4.0			SP - Mottled brown-red fine SAND with trace fines. subangular, well sorted, clast supported, moist. Noted slight petroleum odor.				10	
5.8			SM - Stained black fine SILTY SAND, subangular, moderately sorted, moist. Upper contact - sharp. Noted strong petroleum odor throughout.		4.0		180	Collected Sample SB17-5565 (5.5 - 6.5 feet bgs).
6.3 ▽							100	
8.0			SP - Mottled brown-red fine SAND with trace fines, subangular, well sorted, clast supported, wet.					
			SM - Mottled brown-orange SILTY SAND, subangular, moderately sorted, wet. Upper contact - gradational.		3.5		6	
11.5			End of boring at 11.5 feet bgs.					

DRILLING LOG OF WELL/BORING NO. SB-18

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: West of pumping station fence.

Date Started/Finished: 03 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 13.5
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 8.0 Final: ▼ ____
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.								
	Hydrated Bentonite Seal		*ground surface (gs)*						
1–2			SP - Mottled orange-brown fine SAND with trace fines, subangular, well sorted, clast supported, moist. Noted strong old-gasoline odor.			3.0		95	Collected Sample SB18-0102 (1.0 - 2.0 feet bgs).
3			3.0 No recovery. 4.0						
4–7			SP - Uniformly brown fine SAND with trace fines, subangular, well sorted, clast supported, moist grading wet. Noted strong old-gasoline odor.			4.0		100	Collected Sample SB18-0708 (7.0 - 8.0 feet bgs).
8		▽	8.0						
9–10			SP - Mottled brown-red fine SAND with trace fines, subangular, well sorted, clast supported, wet. Noted strong old-gasoline odor throughout.			3.0		120	
11–12			11.0 SM - Mottled brown-tan SILTY fine SAND, subangular, moderately sorted, clast supported, saturated. Noted free-phase gasoline on water.			2.5		82	
13			13.5 End of boring at 13.5 feet bgs.						
14–15									

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DRILLING LOG OF WELL/BORING NO. SB-19

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Adjacent to northwest corner ASTs.

Date Started/Finished: 04 June 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: GeoProbe - Direct Push

Total Depth of Hole (feet BGS): 8
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: Paul D. James, P.G.

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		ground surface (gs)						
0	Hydrated Bentonite Seal		SW - Stained black-brown SAND with trace fines and fine gravel, angular to subangular, poorly sorted, matrix supported, moist. Noted petroleum odor and staining.					25	Collected Sample SB19-0102 (1.0 - 2.0 feet bgs).
2.5			SP - Stained black-brown, fine SAND with trace fines, subangular, well sorted, clast supported, moist. Upper contact - sharp. Noted petroleum odor and staining throughout.			3.5		40	
4.0			No recovery.					60	
5.2			SM - Stained black with varible brown-orange, SILTY fine SAND with trace CLAY, subangular, well sorted, matrix supported, moist. Upper contact - gradational. Noted petroleum odor and staining throughout.			4.0			
8.0			SM - Mottled brown-black- orange, SILTY fine SAND with little CLAY (~25%), subangular, poorly sorted, matrix supported, moist. Upper contact - sharp.					10	Collected Sample SB19-0708 (7.0 - 8.0 feet bgs).
			End of boring at 8.0 feet bgs. Noted weathered sandstone in foot of macro-sampler.						

DRILLING LOG OF WELL/BORING NO. SB-20

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 1, See Site Map
Date Started/Finished: 04 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: Slam Bar - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 3
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1			Silty Sand (SW-SM) - mottled reddish brown - brown (10YR 3/2), fine grained, subangular, moderately sorted with silt 10% and dryed petroleum fragments < 1% (< 3 mm dia), interbedded with a grey to light brown silty sand stringer @ approx. 0.5 ft. (1 in. thick)			1.8			Sample taken from center of dry stream bed
3			3.0 Total Depth = 3 ft.						
4									
5									
6									
7									
8									
9									
10									

DRILLING LOG OF WELL/BORING NO. SB-21

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 1, See Site Map
Date Started/Finished: 04 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: Slam Bar - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 3
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1			Silty Sand (SW-SM) - mottled reddish brown - brown (10YR 3/2), fine grained, subangular, moderately sorted with silt 10% and dryed petroleum fragments < 1% (< 3 mm dia.)			1.8			Sample taken from center of dry stream bed
2									
3			3.0 Total Depth = 3 ft.						
4									
5									
6									
7									
8									
9									
10									

DRILLING LOG OF WELL/BORING NO. SB-22

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 1, See Site Map
Date Started/Finished: 04 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: Slam Bar - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 3
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1 2 3			Silty Sand (SW-SM) - mottled reddish brown - brown (10YR 3/2), fine grained, subangular, moderately sorted with silt 10% and dryed petroleum fragments < 1% (< 3 mm dia) 3.0 Total Depth = 3 ft.			1.8			Sample taken from center of dry stream bed
4 5 6 7 8 9 10									

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DRILLING LOG OF WELL/BORING NO. SB-23

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 1, See Site Map
Date Started/Finished: 04 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: Slam Bar - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 3
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1–2			Silty Sand (SW-SM) - mottled reddish brown - brown (10YR 3/2), fine grained, subangular, moderately sorted with silt 10% and dryed petroleum fragments < 1% (< 3 mm dia)			1.8			Sample taken from center of dry stream bed
3			3.0 Total Depth = 3 ft.						
4–10									

DRILLING LOG OF WELL/BORING NO. SB-24

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 1, See Site Map
Date Started/Finished: 04 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: Slam Bar - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 2
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1			Silty Sand (SW-SM) - mottled reddish brown - brown (0-0.5 ft.) and hydrocarbon stained (dark brown - green), fine grained, subangular, moderately sorted with silt - 40% , rounded fine gravel - 10% and dryed petroleum fragments - < 1% (< 3 mm dia),			1.0			Sample taken from center of dry stream bed
2			2.0 Refusal @ 2 ft.						Sandstone outcrops can be seen on both banks of stream.
3			Sandstone - reddish brown to tan, well sorted. compacted and poorly cemented						
4			Total Depth = 2 ft.						
5									
6									
7									
8									
9									
10									

DRILLING LOG OF WELL/BORING NO. SB-25

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 1, See Site Map
Date Started/Finished: 04 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: Slam Bar - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 3
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1–3			Silty Sand (SW-SM) - mottled reddish brown - brown (10YR 3/2), fine grained, subangular, moderately sorted with silt 10% and dryed petroleum fragments - < 1% (< 3 mm dia.)			1.8			Sample taken from center of dry stream bed
3.0			Total Depth = 3 ft.						

DRILLING LOG OF WELL/BORING NO. SB-26

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 1, See Site Map
Date Started/Finished: 04 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: Slam Bar - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 3
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
0			Silty Sand (SW-SM) - mottled reddish brown - brown (10YR 3/4), fine grained, subangular, moderately sorted with silt 10% and dryed petroleum fragments < 1% (< 3 mm dia)			1.8			Sample taken from center of dry stream bed
3.0			Total Depth = 3 ft.						

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DRILLING LOG OF WELL/BORING NO. SB-27

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 1, See Site Map
Date Started/Finished: 05 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: Slam Bar - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 3
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1–2			Silty Sand (SW-SM) - mottled reddish brown - brown (10YR 3/6), fine grained, subangular, moderately sorted with silt 49% and dryed petroleum fragments < 1% (< 3 mm dia)			1.8			Sample taken from center of dry stream bed
3			3.0 Total Depth = 3 ft.						

DRILLING LOG OF WELL/BORING NO. SB-28

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 1, See Site Map
Date Started/Finished: 05 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: Slam Bar - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 2
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1			Silty Sand (SW-SM) - mottled reddish brown - brown (7.5YR 3/4) and, fine grained, subangular, moderately sorted with silt - 50% , rounded fine gravel - 49% and dryed petroleum fragments < 1% (< 3 mm dia), Refusal @ 2 ft.			1.8			Sample taken from center of dry stream bed
2			2.0 Total Depth = 2 ft.						
3									
4									
5									
6									
7									
8									
9									
10									

DRILLING LOG OF WELL/BORING NO. SB-29

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 1, See Site Map
Date Started/Finished: 05 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: Slam Bar - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 1
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼ ____
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.								
			ground surface (gs)						
1			Silty Sand (SW-SM) - mottled reddish brown - brown (7.5YR 3/4), fine grained, subangular, moderately sorted with silt 24% and dryed petroleum fragments < 1% (< 3 mm dia), Refusal @ 1 ft. Total Depth = 1 foot			0.8			Sample taken from center of dry stream bed
2									
3									
4									
5									
6									
7									
8									
9									
10									

DRILLING LOG OF WELL/BORING NO. SB-30

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 1, See Site Map
Date Started/Finished: 05 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: Slam Bar - Direct Push. 1 in. dia. hole

Total Depth of Hole (feet BGS): 3
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1			Silty Sand (SW-SM) - mottled reddish brown - brown (10YR 3/6), fine grained, subangular, moderately sorted with silt 10%			1.8			Sample taken from east bank of Lee's pond.
3			3.0 Total Depth = 3 ft.						

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DRILLING LOG OF WELL/BORING NO. SB-31

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 1, See Site Map
Date Started/Finished: 05 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: Slam Bar - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 3
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1			Clayey/Silty Sand (SW-SM) - mottled reddish brown - brown (5YR 4/3), fine grained, subangular, moderately sorted with clay/silt 50%			1.5			Sample taken from west edge of Lee's pond
3			3.0 Total Depth = 3 ft.						
4									
5									
6									
7									
8									
9									
10									

DRILLING LOG OF WELL/BORING NO. SB-32

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 1, See Site Map
Date Started/Finished: 05 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: Slam Bar - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 1
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.								
			ground surface (gs)						
1			Clayey/Silty Sand (SW-OH) - Hydrocarbon stained brownish green to black, fine grained, subangular, poorly sorted with clay/silt 25%, and decayed plant leaves, strong hydrocarbon odor			1.0			Sample taken from the center of West stream bank
			1.0 Total Depth = 1 ft.						
2									
3									
4									
5									
6									
7									
8									
9									
10									

DRILLING LOG OF WELL/BORING NO. SB-33

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 1, See Site Map
Date Started/Finished: 05 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: Slam Bar - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 1
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1			Clayey/Silty Sand and Gravel (SG-OH) - Hydrocarbon stained brownish green to black, fine grained, subangular, poorly sorted with clay/silt 20%, decayed plant leaves and fine to medium grained gravel - 30 %, strong hydrocarbon odor. Total Depth = 1 ft.			1.0			Sample taken from the center of wet stream bed
2									
3									
4									
5									
6									
7									
8									
9									
10									

DRILLING LOG OF WELL/BORING NO. SB-34

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 1, See Site Map
Date Started/Finished: 05 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: Slam Bar - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 1
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1			Clayey/Silty Sand and Gravel (SPG-OH) - Hydrocarbon stained brownish green to black, fine grained, subangular, poorly sorted with clay/silt - 25 %, decayed plant leaves and fine to medium grained gravel - 20 %, strong odor			1.0			Sample taken from the center of wet stream bed
1.0			Total Depth = 1 ft.						
2									
3									
4									
5									
6									
7									
8									
9									
10									

DRILLING LOG OF W[illegible]L/BORING NO. SB-35

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Pond 2 southeast of Lee Residence, See Site Map
Date Started/Finished: 06 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: Slam Bar - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 3
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL / BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*					
1			Silty Sand (Fill) - dark brown, strong hydrocarbon odor					Sample taken from southwest corner of Pond 2
			1.0 Sand and silt (Fill) - grey to light brown, soft, strong hydrocarbon oder		1.8			
2			1.8 Silty Sand (Fill) - dark brown, strong hydrocarbon odor					
3			3.0 Total Depth = 3 ft.					
4								
5								
6								
7								
8								
9								
10								

DRILLING LOG OF WELL/BORING NO. SB-36

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 2, See Site Map
Date Started/Finished: 04 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: JMC - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 9
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 6.5 Final: ▼ ____
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1			Silty Sand (SW-SM) - mottled reddish brown - brown (5YR 5/8), fine grained, subangular, moderately sorted with silt 30%, groundwater @ 6-7 feet. Slight hydrocarbon odor			3.0			Sample taken from east bank of Tributary 2
2									
3									
4						3.0			
5									
6		▽							Laboratory sample taken from 6 - 7 foot interval
7						2.5			
8									
9			9.0 Total Depth = 9 ft.						
10									

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DRILLING LOG OF W. _L/BORING NO. SB-37

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 2, See Site Map
Date Started/Finished: 04 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: JMC - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 9
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 6.5 Final: ▼ ____
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1–2			Silty Sand (SW-SM) - mottled reddish brown - brown (5YR 5/8), fine grained, subangular, moderately sorted with silt 30%, groundwater @ 6-7 feet.			3.0			Sample taken from east bank of Tributary 2
3–5						3.0			
6–7									Laboratory sample taken from 6 - 7 foot interval
7–8						3.0			
9			9.0 Total Depth = 9 ft.						
10									

DRILLING LOG OF WELL/BORING NO. SB-38

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 2, See Site Map
Date Started/Finished: 04 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: JMC - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 9
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 1 Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL / BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*					
1		▽	Silty Sand (SW-SM) - mottled reddish brown - brown (5YR 5/8), fine grained, subangular, moderately sorted with silt 30%. Moist soil at 1 ft.		3.0			Sample taken from east bank of Tributary 2 Laboratory sample taken from the 0-1 foot interval
2								
3					3.0			
4								
5								
6					2.5			
7								
8								
9			9.0 Total Depth = 9 ft.					
10								

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DRILLING LOG OF WELL/BORING NO. SB-39

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 2, See Site Map
Date Started/Finished: 05 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: JMC - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 9
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 3.5 Final: ▼ ____
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1–3			Silty Sand (SW-SM) - mottled reddish brown - brown (5YR 5/8), fine grained, subangular, moderately sorted with silt/ clay - 40%, groundwater @ 3 - 4 feet.			3.0			Sample taken from east bank of Tributary 2
3–5						2.5			Laboratoty sample taken fro 3 - 4 foot interval
6–9						3.0			
9			9.0 Total Depth = 9 ft.						
10									

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DRILLING LOG OF WELL/BORING NO. SB-40

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 2, See Site Map
Date Started/Finished: 06 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: JMC - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 6
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 3.5 Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1–2			Silty Sand (SW-SM) - mottled reddish brown - brown (5YR 5/8), fine grained, subangular, moderately sorted with silt/ clay - 40%, groundwater @ 3 - 4 feet.			3.0			Sample taken from east bank of Tributary 2
3–5						3.0			Laboratory sample taken from the 3 - 4 ft. interval
6			6.0 Total Depth = 6 ft.						

DRILLING LOG OF W. L/BORING NO. SB-41

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 2, See Site Map
Date Started/Finished: 06 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: JMC - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 6
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 2.5 Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1–2			Silty Sand (SW-SM) - mottled reddish brown - brown (5YR 5/8), fine grained, subangular, moderately sorted with silt/ clay - 40%, groundwater @ 2 - 3 feet.			3.0			Sample taken from west bank of Tributary 2
3–4						3.0			Laboratory sample taken from the 3 - 4 ft. interval
6			6.0 Total Depth = 6 ft.						

DRILLING LOG OF WELL/BORING NO. SB-42

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 2, See Site Map
Date Started/Finished: 06 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: JMC - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 6
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 2.5 Final: ▼ ____
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1–3			Silty Sand (SW-SM) - mottled reddish brown - brown (5YR 5/8), fine grained, subangular, moderately sorted with silt - 30% and petroleum globuals < 1% (< 3 cm dia), groundwater encountered @ 2 - 3 ft.			3.0			
3–6						3.0			Laboratory sample taken from the 2 - 3 ft. interval
6			6.0 Total Depth = 6 ft						

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DRILLING LOG OF W. L/BORING NO. SB-43

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 2, See Site Map
Date Started/Finished: 05 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: JMC - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 9
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 6.5 Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1			Silty Sand (SW-SM) - mottled reddish brown - brown (5YR 5/8), fine grained, subangular, moderately sorted with silt/ clay - 30%, groundwater @ 6 - 7 feet.			3.0			Sample taken from west bank of Tributary 2
2									
3									
4						3.0			
5									
6									Laboratory sample collected from 6 - 7 ft. interval
7						2.5			
8									
9			9.0 Total Depth = 9 ft.						
10									

DRILLING LOG OF WELL/BORING NO. SB-44

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 2, See Site Map
Date Started/Finished: 05 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: JMC - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 6
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 4.5 Final: ▼ ____
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
1			Silty Sand (SW-SM) - mottled reddish brown - brown (5YR 5/8), fine grained, subangular, moderately sorted with silt/ clay - 30%, groundwater @ 4 - 5 feet. Refusal @ 6 ft.			3.0			Sample taken from west bank of Tributary 2
2									
3									
4		▽				3.0			Laboratory sample collected from 4 - 5 ft. interval
5									
6			6.0 Total Depth = 6 ft.						
7									
8									
9									
10									

ecology and environment, inc.

WELL_LOG WILCOX.GPJ 9-29-98

DRILLING LOG OF WELL/BORING NO. SB-45

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Tributary 2, See Site Map
Date Started/Finished: 05 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: JMC - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 6
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ 1 Final: ▼
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
0			Silty Sand (SW-SM) - mottled reddish brown - brown (5YR 5/8), fine grained, subangular, moderately sorted with silt/ clay - 40%, groundwater @ 1 feet. Refusal @ 6 ft.			3.0			Sample taken from west bank of Tributary 2 Laboratory sample from 0 - 1 ft.
1		▽							
2									
3						2.5			
4									
5									
6			Total Depth - 6 ft.						
7						3.0			
8									
9			9.0						
10									

ecology and environment, inc.

DRILLING LOG OF WELL/BORING NO. SB-46

Project/Location: Wilcox Refinery / Bristow, Oklahoma
Boring Location: Pond 2 east of (b) (6) Residence
Date Started/Finished: 06 August 1998/
Drilling Contractor: Ecology & Environment, Inc.
Drill Method: JMC - Direct Push, 1 in. dia. hole

Total Depth of Hole (feet BGS): 12
Ground Elevation (feet above): Unknown
Inner Casing Elevation (TOC): N/A
Groundwater Depth (feet BGS):
First Encountered: ▽ N/A Final: ▼ ____
Geologist: L. Williams

ELEVATION / DEPTH (feet)	WELL COMPLETION DIAGRAM	GRAPHIC LOG	SOIL/ROCK DESCRIPTION	SAMPLE INTERVAL	BLOW COUNT	RECOVERY (feet)	LEL (%)	PID [FID] (ppm)	COMMENTS
Ground Surface Elevation Unknown	Monitoring well was not installed at this boring location.		*ground surface (gs)*						
0			Clayey/Silty Sand (Fill) - dark brown, strong hydrocarbon odor						Sample taken near center of Pond 2
1.0			Clayey/Silty Sand (Fill) - light brown - grey, strong hydrocarbon odor, soft			3.0			
2.0			Clayey/Silty Sand (Fill) - dark brown, strong hydrocarbon odor						
3									
4						3.0			
5									
6									Composite sample collected from 6 - 12 ft.
7									
8						3.0			
9									
10									
11						2.5			
12			12.0 Total Depth = 12 ft.						
13									
14									

ecology and environment, inc.

Appendix B
Records of Communication
(6 Pages)

Tom Beer
Print Originator's Name
Ecology and Environment, Inc.

RECORD OF COMMUNICATION

Conversation with:	Date 03 / 18 / 98 (Mo) (Day) (Year)
Name: (b) (6)	Time: 11:00 AM
Address: (b) (6) Bristow, OK 74010	[X] Originator Placed Call
Phone: (b) (6)	[] Originator Received Call
Subject: Site Access	

Discussion:

(b) (6) is the owner of the 80-acre former tank farm area comprising most of the Wilcox Refinery site. (b) (6) gave verbal approval for EPA and START to access the property for a site reconnaissance visit and will sign the formal Access Agreement upon receipt. The property is mostly fenced but the access gate from the north-central side of the site is not locked. (b) (6) requested a copy of the ESI so I referred him to ODEQ and the EPA. Also, (b) (6) is in the process of selling the property and has conducted some remediation at the site including bulldozing soil over oily waste at the surface within tank berms, at Pond 1, and on the oily waste "Pit". The heavy equipment and operators were apparently provided by Tenneco Oil Company.

Follow-Up-Action:

Mail site access consent agreement to (b) (6)

Originator's Signature T. Beer

Tom Beer
Print Originator's Name
Ecology and Environment, Inc.

RECORD OF COMMUNICATION

Conversation with:	Date 03 / 19 / 98 (Mo) (Day) (Year)
Name: (b) (6)	Time: 10:00 AM
Address: (b) (6) Bristow, OK 74010	[X] Originator Placed Call
Phone: (b) (6)	[] Originator Received Call
Subject: Site Access	

Discussion:

(b) (6) is the co-owner of the 13 to 20-acre former refinery area comprising most of the western end of the Wilcox Refinery site. (b) (6) gave verbal approval for EPA and START to access the property for a site reconnaissance visit but stated that his son, (b) (6) is the other co-owner of the property and would have to be contacted for signing the formal Access Agreement The property is fenced. and keys to the access gate at the north end of the property can be obtained from (b) (6) would like to have a family member present during the site visit.

(b) (6) discussed a number of issues related to environmental assessment of the site:

- (b) (6) acquired the property from Jim Bankston (JB) in about 1969. The large tanks were mostly salvaged for scrap iron by JB from 1965 to 1966. The tank bottom sludge (TBS) were burnt to reduce the liguid content prior to cutting the tank walls down to ground level. The tank base steel was mostly left in place:
- Three medium size above-ground storage tanks (ASTs) and one small AST remain on site. Two in the far northwest corner of the are mostly intact and have a thin layer of residual sludge and rain water in the base. one medium-size tank at the south end of the is just a shell. and the one-small. circular tank with a conical roof in the center of the property has a small. unknown quantity of sludge or 'burner fuel' in its base.
- A third property owner lives in a trailer on approximately 4 acres of land to the east of (b) (6)s property. (b) (6) apparently have an unlisted phone number. The area around the (b) (6) residence was sampled in 1996 during the ESI by Weston.

Follow-Up-Action:

Contact the remaining property owners on the Wilcox Refinery site: (b) (6).
Mail site access consent agreement to (b) (6).

Originator's Signature T. Beer

Tom Beer
Print Originator's Name
Ecology and Environment, Inc.

RECORD OF COMMUNICATION

Conversation with:	Date 03 / 19 / 98 (Mo) (Day) (Year)
Name: Mr. Hal Cantwell and Mr. Karën Khalafian	Time: 11:00 AM
Address: Oklahoma Department of Environmental Quality (ODEQ), Tulsa, OK	[X] Originator Placed Call
Phone: (405) 271-7158 and (405) 702-5115	[] Originator Received Call
Subject: ODEQ Involvement at Wilcox Refinery	

Discussion:

Mr. Cantwell is the supervisor of the Site Assessment Group at ODEQ in Tulsa. He confirmed ODEQ has knowledge and experience at the site, but that no site-specific investigation of the site is being conducted currently. Mr. Cantwell referred me to Mr. Khalafian who is currently conducting a site investigation at the adjacent Ohio Oil Refinery site to the north of Wilcox, that includes a regional groundwater study.

Mr. Khalafian (KK) was helpful in providing background information for the area and the status of current ODEQ activities. The original

Wilcox Refinery included the Ohio Oil Refinery site (north) and the Lorraine Refinery site (west) of the current EPA Wilcox project site. KK is sampling domestic and municipal wells in and around the project area and the City of Bristow, during the week of March 23. KK agreed to provide START with analytical results upon completion. KK provided the following aquifer information:

- a shallow aquifer occurs at about 30 ft. bgs and domestic wells are screened at 60 to 70 ft. bgs;
- shallow wells at the First Assembly Church (Lorraine Refinery) and (b) (6) property have been closed recently due to hydrocarbon odor and taste:
- deeper wells for the City of Bristow are screened at about 200 ft. bgs and produce good water.

KK will provide copies of relevant aerial photos and Sanborn maps when we meet onsite next week or during subsequent field work.

Follow-Up-Action:

Originator's Signature J. Beer

Tom Beer
Print Originator's Name
Ecology and Environment, Inc.

RECORD OF COMMUNICATION

Conversation with:	Date 03 / 25 / 98 (Mo) (Day) (Year)
Name: (b) (6)	Time: 16:55 PM
Addre (b) (6) Bristow, OK 74010	[] Originator Placed Call
Phone	[] Originator Received Call
Subject: Site Access	

Discussion:

Meet (b) (6) by chance at his driveway entrance during the START site reconnaissance visit on 3/25/98. (b) (6) readily provided his unlisted phone number, address, and verbal permission to access his property. He stated that his security precautions and warning signs were mostly to keep out rowdy teenagers and prevent crank phone calls. (b) (6) and his wife (b) (6) have only owned the 3.6-acre lot since 1996, and don't know any site history. They have areas of oily waste at the surface surrounding their trailer home. mostly outside the inner fenceline. Gas and water utility lines follow south along the west side of the gravel access road and angle southwest toward the house from a point on the access road near the gas meter.

Follow-Up-Action:

Mail site access consent agreement to (b) (6)

Originator's Signature J. Beer

Tom Beer
Print Originator's Name
Ecology and Environment, Inc.

RECORD OF COMMUNICATION

Conversation with:	Date 04 / 08 / 98 (Mo) (Day) (Year)
Name: (b) (6)	Time: 10:30 AM
Address: (b) (6) Bristow, OK 74010	[] Originator Placed Call
Phone: (b) (6)	[] Originator Received Call
Subject: Site Access	

Discussion:

Meet (b) (6) at his business prior to the START site reconnaissance visit to (b) (6) property on 3/25/98. (b) (6) gave verbal permission to access his property and arranged for his brother (b) (6), who lives in the site residence, to open the gate and accompany us onsite. (b) (6) can provide a gate key to START for easier access during field work.

Follow-Up-Action:

Originator's Signature J. Beer

Tom Beer
Print Originator's Name
Ecology and Environment, Inc.

RECORD OF COMMUNICATION

Conversation with:	Date 05 / 28 / 98 (Mo) (Day) (Year)
Name: Ms. Linda Tate	Time: 10:00 AM
Address: Administrator. City of Bristow, Bristow. OK 74010	[X] Originator Placed Call
Phone: (918) 367-6233	[] Originator Received Call
Subject: Informing the Mayor of EPA START Site Activity at Wilcox Refinery	

Discussion:

Initially START left a message with Ms. Tate on 4/27/98 to inform the Mayor of proposed field investigation activities to be performed at Wilcox Refinery. The first field sampling event was postponed due to heavy rain and muddy site conditions. Ms. Tate was contacted again prior to the second field mobilization to inform the City of Bristow of further site activities. Ms. Tate will inform the Mayor and alerted START that more rain fell in the area on Tuesday 5/26/98. Ms. Tate was also aware of the water well testing conducted by ODEQ in March, 1998.

Follow-Up-Action:

Originator's Signature T. Beer